WATER & SEWAGE WORKS

WATER SUPPLY • INDUSTRIAL WASTE TREATMENT • SEWAGE DISPOSAL

MAY, 1953

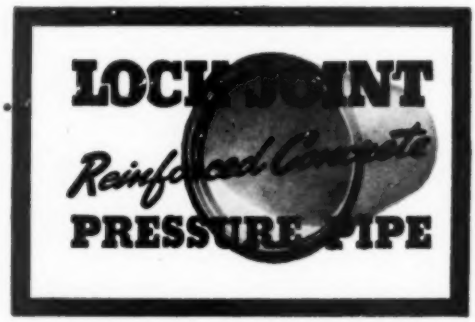
LOCK JOINT serves the SOUTH

IF YOU'RE FROM THE SOUTH . . .
specifically Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Kentucky or Tennessee . . . our plant at Columbia, South Carolina, is ready and waiting to serve you. This Columbia plant, the fourth of our up-to-date permanent pressure pipe manufacturing yards, is equipped to produce Lock Joint Prestressed Concrete Cylinder Pipe in diameters from 16″ to 48″, designed for any pressure common to water works practice. The plant's central location in the Southeast makes it possible to deliver the completed pipe speedily and economically throughout this area.

IF YOU'RE FROM ANY OTHER PART OF THE COUNTRY EAST OF THE ROCKIES . . . our three other permanent pressure pipe plants located at Wharton, N. J.; Detroit, Mich.; and Turner, Kansas, stand ready to provide for your complete Reinforced Concrete Pressure Pipe requirements. All these plants are equipped to manufacture the most carefully designed modern Concrete Pressure Pipe in a large range of standard diameters, and have facilities to handle any contract however large or small.

SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains 16″ in diameter or larger, as well as Concrete Pipes of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

LOCK JOINT PIPE COMPANY
Established 1905
P. O. Box 269, East Orange, N. J.
PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kan., Detroit, Mich., Columbia, S. C.
BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. • Denver, Col. • Kansas City, Mo. • Valley Park, Mo. • Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. Mex. • Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis. • Hato Rey, P. R. • Caracas, Venezuela



Put a HOMELITE CARRYABLE PUMP on YOUR Job and Eliminate Delays

On any repair or construction job, water causes delays. And delays cost money . . . particularly when men have to stand around idle.

Put a Homelite Pump on the job and watch those delays disappear. In no time it *gets* to the job . . . no trucking problems, no planking, no pushing, no pulling. One man carries it and sets it up right where you need it. Quick starting . . . and with the fastest self-priming . . . a Homelite will pump up to 15,000 gallons per hour without clogging or trouble. It draws water 28 feet and of great importance it will keep seepage at strainer level automatically.

Figure it out, with the time . . . which is money . . . saved by a fast-action Homelite it wouldn't take many jobs to pay for a Homelite. Possibly, one job would be enough. Write for a free demonstration.

Manufacturers of Homelite Carryable Pumps • Generators Blowers • Chain Saws

PERFORMANCE • DEPENDABILITY • SERVICE

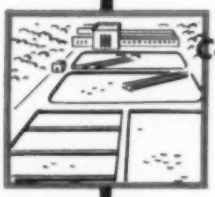
HOMELITE CORPORATION

705 RIVERDALE AVENUE • PORT CHESTER, N. Y.

Canadian Distributors: Terry Machinery Co., Ltd., Toronto, Montreal, Vancouver, Quebec.

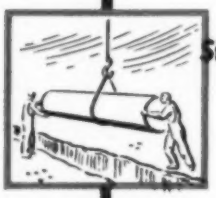
keep HTH GRANULAR on hand for

LOOK FOR HTH in this new lithographed drum. HTH Granular is the same dependable product as Sanitation HTH . . . only the package is changed. HTH contains 70% available chlorine and is packaged in 100-lb. drums and in cases of nine handy 5-lb. cans.



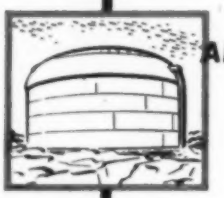
Continuous Chlorination

A safe, easy-to-use source of chlorine for regular water treatment.



Sterilization of New Mains

Makes an effective, economical solution for sterilizing new mains, pumps, standpipes and supply equipment.



Algae Control

In reservoirs, basins, wells, tanks and flumes, HTH is a widely accepted agent for the control of algae.

Emergency Chlorination

In case of flood, drought, fire or power failure, HTH is a readily available source of chlorine.

HTH Tablets *and the* HTH TABLET HYPOCHLORINATOR

For safe, dependable, metered chlorine solutions, investigate the many advantages of Hypochlorination with HTH Tablets. Write for full information.

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MATHIESON CHEMICAL CORPORATION
Mathieson Industrial Chemicals Division
Baltimore 3, Maryland

1548

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WATER & SEWAGE WORKS

WATER SUPPLY • SEWAGE DISPOSAL
INDUSTRIAL WASTE TREATMENT

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OUR FRONT COVER is another of a series of cover pictures symbolizing life-giving WATER—*"God's Highest Gift to Man."* This full color photograph of the spectacular Wenatchee River, which roars down out of the great Cascades of Northern Washington was taken by the Northwest's internationally known scenic photographer RAY ATKESON of Portland, Ore.

Special process color plates by Cochran Corp., of Milwaukee, reproduced by Kable Printing Co. on "Kromekote" cover stock

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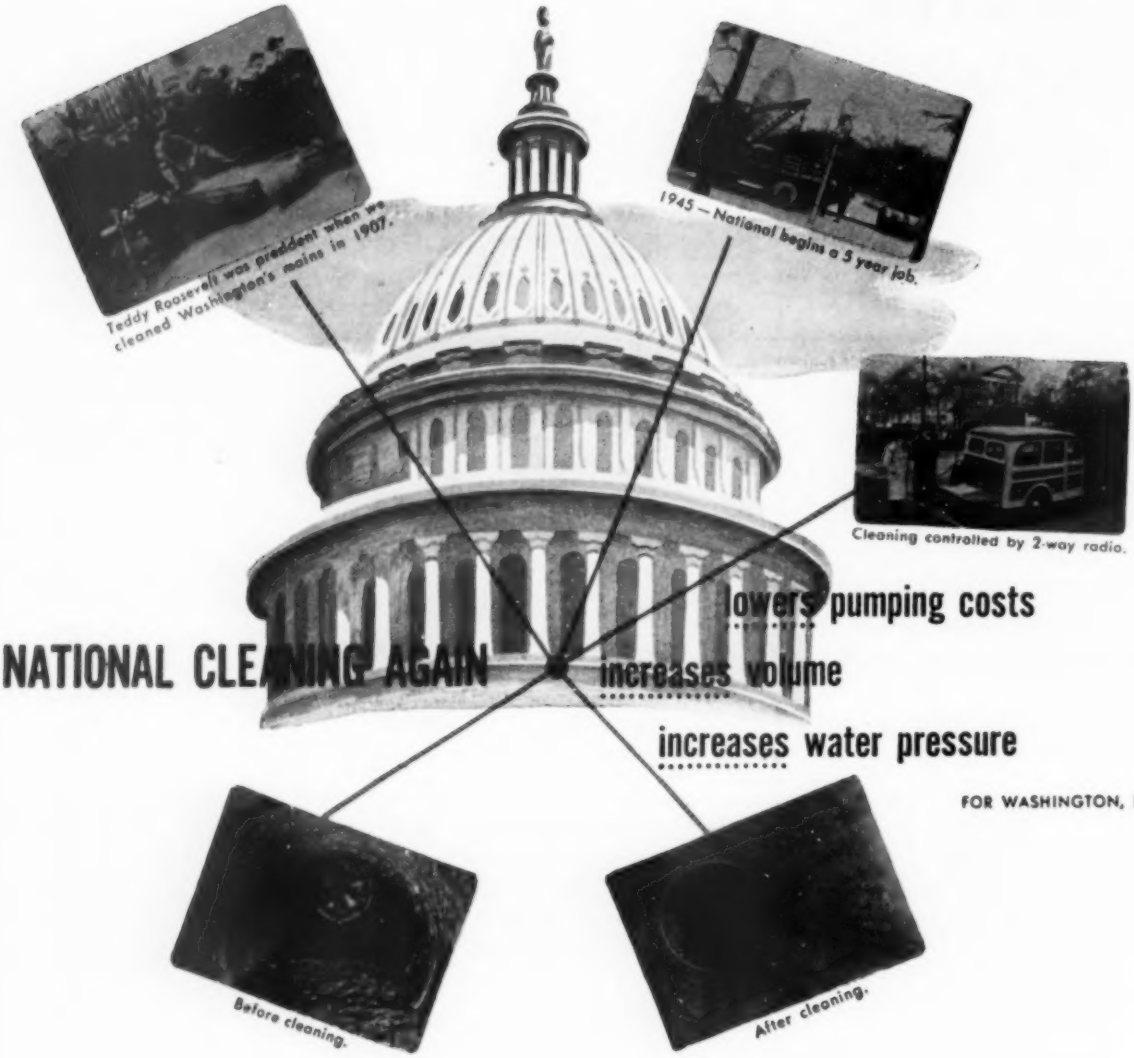
Teddy Roosevelt was president when we cleaned Washington's mains in 1907.
1945 — National begins a 5 year job.
Cleaning controlled by 2-way radio.
NATIONAL CLEANING AGAIN
lowers pumping costs
increases volume
increases water pressure
FOR WASHINGTON, D. C.
Before cleaning.
After cleaning.

Way back in 1907 and again in 1926 National successfully cleaned the water mains of Washington, D. C.

In 1945 a five year program to clean and recondition the water main system of Washington was begun and National in conjunction with the Centriline Corporation was successively awarded the cleaning contracts for 1945, 1946, 1947, 1948 and 1949. At the completion of these contracts, National was awarded additional cleaning contracts for 1950, 1951 and 1952 — in short, all the cleaning jobs to date.

Tests made on those lines already cleaned and centrilined indicate a co-efficient of over 130 as against less than 90 before cleaning, resulting in lower pumping costs, increased volume and higher pressure.

Let us estimate the cost of restoring your lines to at least 95% of their original carrying capacity. Write today.

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IN LOS ANGELES

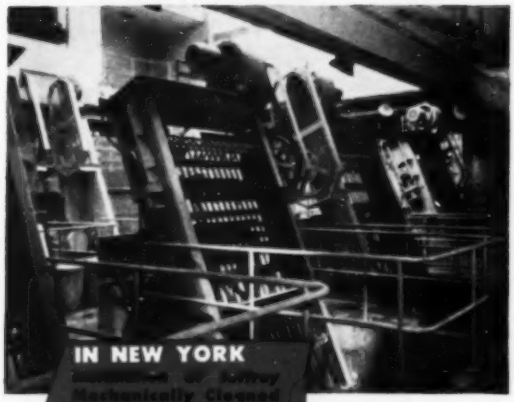
Aeration Primary Settling Tanks at the Hyperion Activated Sludge Plant

"from coast to coast"

MODERN SANITATION PLANTS rely on JEFFREY

IN CHICAGO

Concentration Tanks at Calumet Activated Sludge Plant



IN NEW YORK

Mechanically Cleaned Bar Screens for sewage treatment

Wherever you're located — whatever the Sanitation problem — Jeffrey has both the background and equipment to help you. That's why you find more and more communities all over the nation consulting Jeffrey on every problem concerning water, sewage and industrial waste treatment.

Look at the three installations pictured here. They happen to be in three of the largest cities in the country. But smaller communities, as well as industrial plants, are also calling in Jeffrey engineers for complete new installations or modernization to improve water, sewage and waste treatment.

Jeffrey Equipment includes Bar and Disc Type Screens, Screenings Grinders, Grit Collectors and Washers, Sludge Collectors and Elevators, FLOCTROLS, Scum Removers, Dry Feed Chemical Machines, Biofiltration Plant Equipment, Garbage Grinders, Elevators, Conveyors, Chains and Sprockets and Power Transmission Equipment. Write our Sanitation Department for Catalog 833.

THE JEFFREY MANUFACTURING CO.

ESTABLISHED 1877

Columbus 16, Ohio

sales offices and distributors in principal cities

PLANTS IN CANADA, ENGLAND, SOUTH AFRICA

IF IT'S MINED, PROCESSED OR MOVED . . . IT'S A JOB FOR JEFFREY!

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PACIFIC FLUSH TANK CO.

Waste Treatment Equipment Exclusively Since 1893

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How Layne assures your water supply

UNDIVIDED LAYNE RESPONSIBILITY MEANS COMPLETE SERVICE, LOWER COSTS

Layne surveys and test wells

Layne's *complete* service begins long before the wells are drilled . . . with geological surveys made in cooperation with engineers of the client company or municipality. Test - hole drilling shows actual conditions.

Layne analyses and recommendations

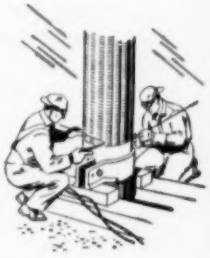
Samples taken from the test holes go to Layne's central laboratories, where technicians report on the earth structure and qualities of the water. From these reports, water-system recommendations are made.

Layne-engineered pumps, screens, casings

Into every Layne well goes equipment designed for the specific job—the finest equipment, produced with the greatest economy, because of Layne's thorough engineering skill and world-wide experience.

Layne installation and maintenance service

Skilled Layne workmen handle every stage of the job—assuring a system custom-engineered for your own situation. And Layne's experience is always at your service for any maintenance work you may need.

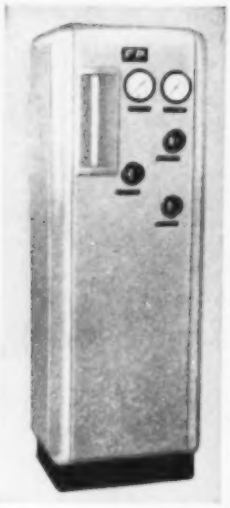


Let Layne help you plan ahead on your water needs

Layne welcomes the opportunity to share in long-range planning for your water-supply needs. For information on any phase of well water supply or pump equipment, contact your nearest Layne Associate Company or write Layne & Bowler, Inc., General Offices, Memphis 8, Tenn.

WATER WELLS • VERTICAL TURBINE PUMPS
WATER TREATMENT

Layne Associate Companies Throughout the World

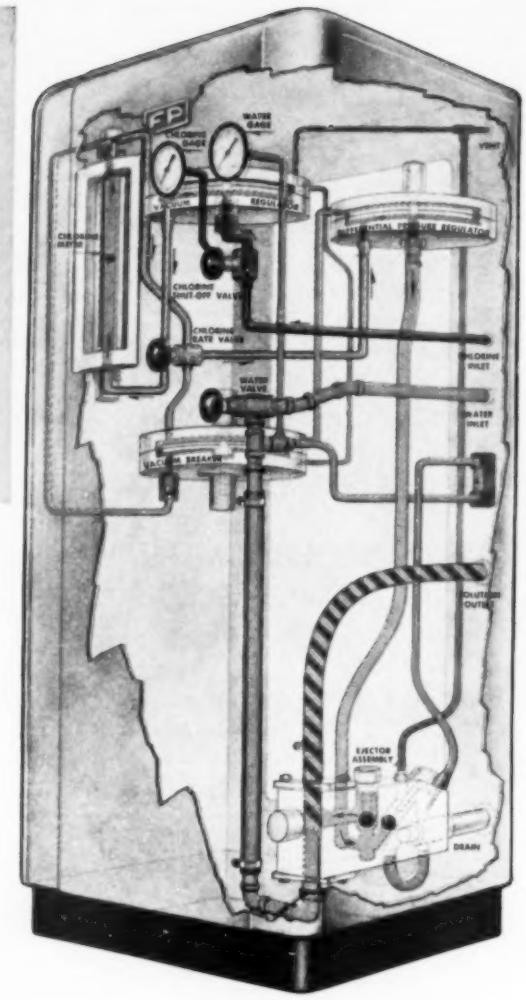


new

RATOCHLOR 1050

CHLORINE DISPENSER

every inch corrosion resistant



From cabinet to valves, every part of the new Ratochlor unit is as corrosion resistant as modern science and technology can make it, the result of years of field and laboratory tests in the handling of both dry and moist chlorine gas.

The complete outer cabinet is made of a new polymer-impregnated fibre glass material, whose attractive grey color permeates the entire material.

Control operations inside the cabinet center around a corrosion resistant Flowrator meter, which provides direct, accurate, wide range of chlorine flow rate. New corrosion resistant materials recently developed in the research laboratories make it possible to incorporate the safety and simplicity of the diaphragm-regulator principle in the 1050 Ratochlor. Water seals are eliminated.

The design of the new 1050 Ratochlor provides the fullest control of chlorine solutions, the most advanced materials and methods to combat corrosion. It can be readily adapted for program control, proportioning and remote control. A complete and comprehensive discussion of the new 1050 Ratochlor and its operation is available in booklet form. Write for Catalog 61 now.

CHECK THESE ADVANTAGES

- SAFETY
- complete corrosion resistance — using Uscolite, Teflon Kel-F, Tantalum and other materials
- direct, visible flow measurement
- maximum water economy
- dependability — minimum working parts
- solution feed standard (gas feed available)
- constant vacuum
- manual rate adjustment

FP

FISCHER & PORTER CO.
2950 County Line Road
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FLOWRATOR

FP 2110

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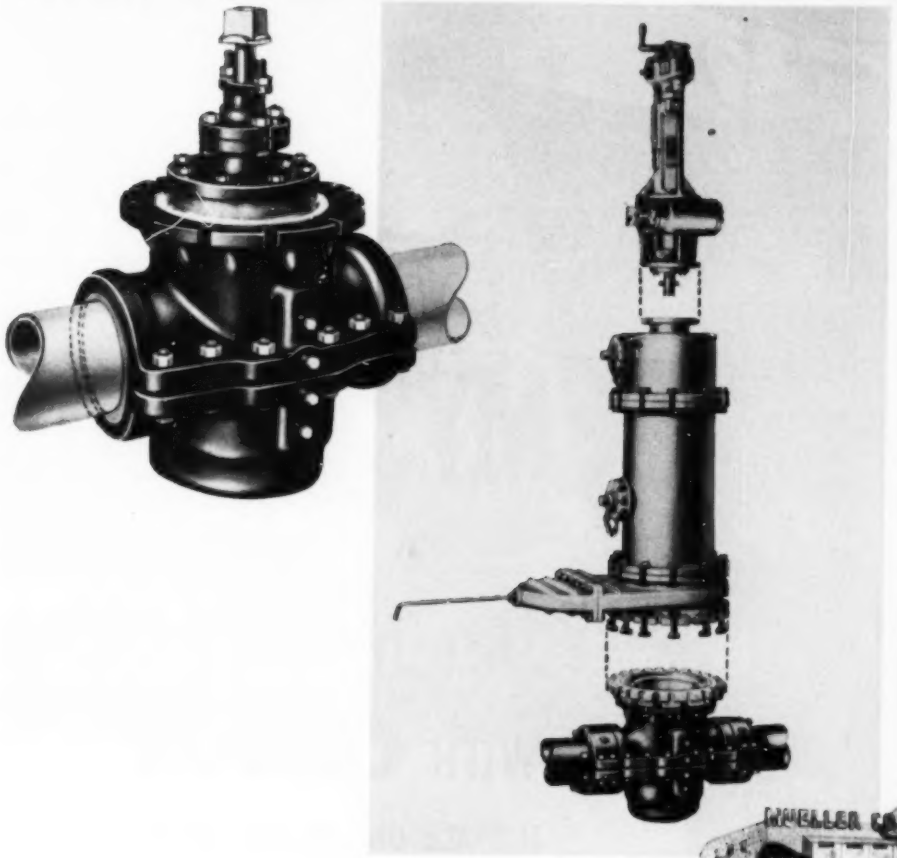

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Drop in and see the new Mueller
Inserting Valve and Equipment Exhibit at the
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Dependable Since 1857

MAIN OFFICE & FACTORY DECATUR, ILLINOIS

there's nothing MYSTERIOUS about Threshold Treatment with CALGON*

IT'S ALL OUT IN THE OPEN

when we talk about Threshold Treatment with Calgon. This treatment is simple and effective *and* economical. Threshold Treatment with Calgon has solved some of the toughest problems that have bothered users of municipal and industrial waters.

There's a reason: Threshold Treatment with Calgon does the following:

- **PREVENTS LIME SCALE**
- **CONTROLS CORROSION**
- **STABILIZES DISSOLVED IRON AND MANGANESE**
- **STABILIZES WATER FOLLOWING SOFTENING**

Write us a letter and tell us your municipal and industrial water problems.

HAGAN HALL BUROMIN CALGON

*T.M. Reg. U.S. Pat. Off.

calgon, inc.

A SUBSIDIARY OF HAGAN CORPORATION
HAGAN BUILDING, PITTSBURGH 30, PA.

Lithographed on stone for U. S. Pipe and Foundry Co. by John A. Noble, A. N. A.

PIPE LINE CREWS encounter all kinds of conditions from deep woods to the congested streets in the heart of a large city's business district. This cast iron pipe installation could be either a water supply line from a mountain reservoir or a sewer force main leading to a remote treatment plant. If it were a gas transmission line it would, of course, be mechanical joint pipe.

U. S. cast iron pipe in sizes from 2-inch through 24-inch are cast *centrifugally* in metal molds with bell-and-spigot, mechanical joints and plain ends. The *pit cast* process is used in producing all sizes of flexible joint and flange pipe as well as all pipe 30-inch and larger. Highly developed production controls guard the uniformly high quality of U. S. Cast Iron Pipe.

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General Offices, Burlington, N. J.
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cast iron
PIPE
FOR WATER, GAS, SEWERAGE AND INDUSTRIAL SERVICE

The Symbol for Service, Quality and Performance in Water Meters

Rockwell Meter Service Aids

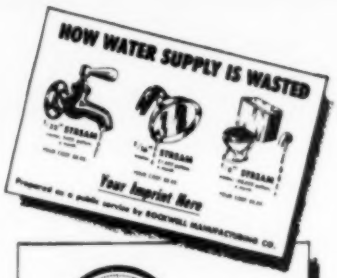
YOURS FOR THE ASKING In the Interests of a Better Public Understanding of the Great and Growing Water Works Industry.

MADE TO MEASURE

A Film Illustrating Your Silent, Faithful Friend—the Water Meter. A 16 mm film utilizing sound and color—running time, 30 minutes. This movie is now available for showings at association meetings, civic groups and educational institutions. When requesting a print, please anticipate your needs by at least a month and if possible give an alternate date.

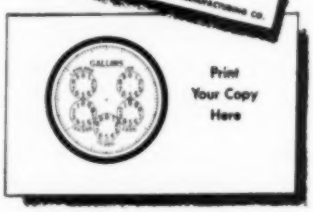
Water Waste Post Cards

Illustrate how water is wasted by small leaks. Cuts available for imprinting post cards or for use in newspapers.



"Read Your Own Meter" Post Cards

Cuts of dial faces of registers are available for printing these cards. Specify type of register cut desired, i.e. whether straight or circular reading, recording in gallons or cubic feet.



Portfolio of Facts on Advantages of 100% Metering

Contains case histories of "before and after" metering experiences, reprints of prize winning essays on 100% metering, publicity stories for release to local newspapers.

ROCKWELL MANUFACTURING COMPANY

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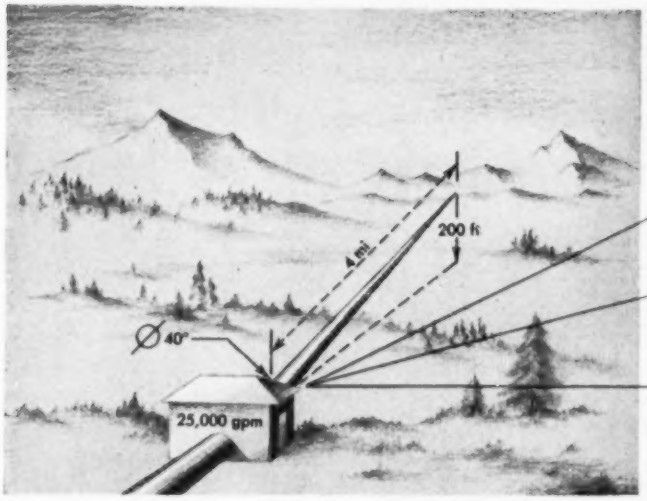
LOS ANGELES NEW YORK PITTSBURGH SAN FRANCISCO SEATTLE TULSA



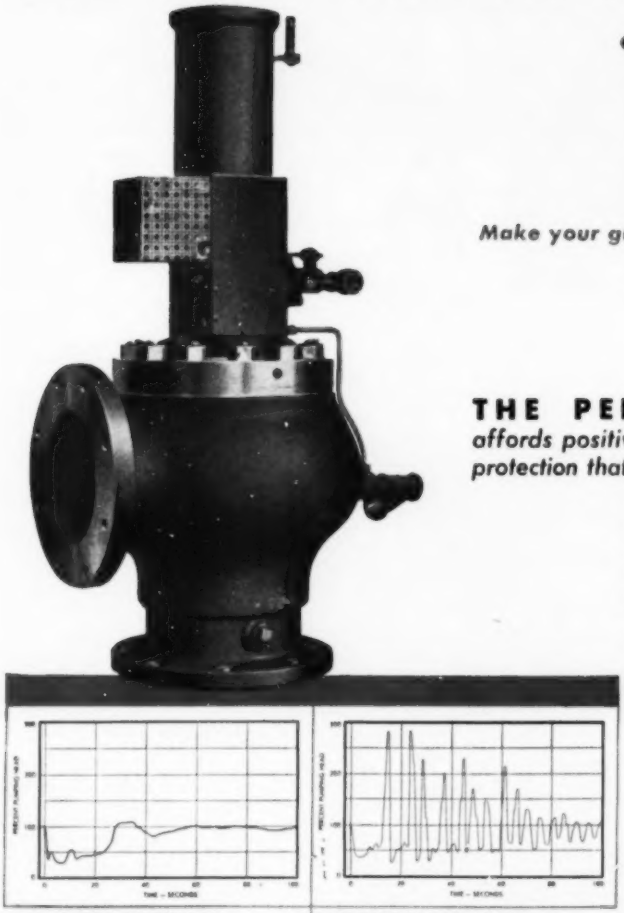
250 feet of head

525 feet of head

975 feet of head

?

CAN YOU PICK THE CORRECT ANSWER?



WITH SURGE SUPPRESSOR

WITHOUT SURGE SUPPRESSOR

● **Here is the problem:** Estimate how high total pressure head could rise from surge if power failure brought the pump in this system to an abrupt stop.

25,000 gallons per minute are being pumped up an elevation of 200 feet in a total pipeline length of 4 miles. Pumping head is 250 feet. Pipe diameter is 40 inches. A check valve is used to stop backflow through the pump.

Make your guess, then here is the answer

Total pressure head could rise as high as 975 feet. Inertia of the upward moving column of water builds up great potential energy. As the water settles back against the check valve, a succession of dangerous pressure waves occurs, often sufficient to burst the pipeline.

THE PELTON SURGE SUPPRESSOR

affords positive protection against this ever present danger — protection that no other valve gives.

Either current stoppage or pressure build-up actuates the **PELTON** Surge Suppressor. This quick-opening valve anticipates return surges and dissipates them by by-passing water around the pump; then it slowly closes as the pressure waves cease.

Lower pipeline costs can more than pay for a **PELTON** Surge Suppressor. Extra weight is eliminated because the pipe need not be designed with large safety factors in anticipation of high surge pressures. The possibility of line failures and interrupted service is greatly decreased.

Installations needing protection occur wherever water is pumped to a higher elevation either through a long pipeline or at high velocity. **PELTON** Surge Suppressors can be furnished to protect waterlines of any size handling service pressures up to 800 p.s.i.

Send us your problem and include pipeline profile. Our engineers will make recommendations without obligation.

The PELTON WATER WHEEL Company

Subsidiary of Baldwin-Lima-Hamilton Corporation

2929 NINETEENTH STREET • SAN FRANCISCO 10, CALIFORNIA

Information courtesy Mr. E. H. Aldrich, Chief Engineer, American Water Works Service Co., Phila., Pa.

There are four purification units like this at Chattanooga with a rated capacity of 2.5 mgd each, capable of operating at twice this capacity. These are an addition to the existing plant of 32 mgd capacity.

Two years ago, this entirely new design developed by American Water Works Service Company was installed in Alexandria, Va. Instead of the conventional layout, with separate structures for mixing, settling, etc., this plant has "*purification units.*" Each unit incorporates all the major purification operations . . . i.e. after the raw water is chemically treated, it receives the usual mixing, coagulating, settling, and filtering, all in the same steel tank (see drawing).

The success of the plant has led to two new installations—Chattanooga, Tenn., and Westmoreland County, Pa. Like Alexandria, both these plants cost far less to build than comparable units of conventional design. All three plants have proved to be easy and economical to operate, and highly flexible.

The porous underdrains used in all these purification units are ALOXITE aluminum oxide plates. These should contribute materially to continued low operating and maintenance costs.

May we send you our popular booklet on porous media? It's 56 pages cover all fields of filtration and diffusion. It gives pointers on specifying materials; outlines how to install, operate and maintain various units. Complete with photos, charts, etc.

Use porous plates and diffusers by

CARBORUNDUM

Trade Mark

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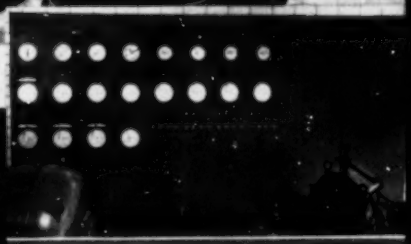
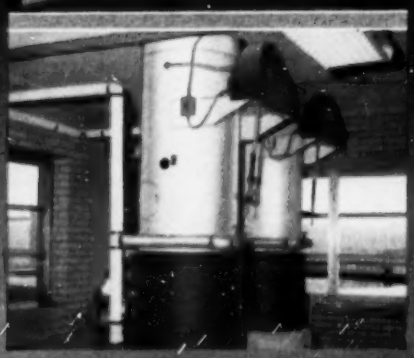
WESTMORELAND COUNTY
(Municipal Authority) Pennsylvania
Beaver Run Filter Plant
(COMPLETED IN 1952)

AMERICAN WATER WORKS SERVICE COMPANY, INC.
Engineers
PHILADELPHIA, PA.

WARE LABORATORIES, INC.
Contractors
GREENSBURG, PA.





B-I-F Industries Equipment furnished for the Beaver Run Filter Plant:

OMEGA

2 — Universal Feeders for hydrated lime
2 — Dissolving Chambers
2 — Universal Feeders for carbon
3 — Hopper Agitators — standard plate type

BUILDERS

Propeloflo Meter — Wash Water Tank Fill Line
Propeloflo Meter with remote Totalizer — Service Water
Chronoflo Transmitters and Receivers — Industrial Water Service, Wash Water Level and Flow
Flo-Watch Registers — Raw Water and High Service
Model RCE Rate-of-Flow Controllers — Filter Effluent and Wash Water
Liquid Level Indicating Gauges—Clear-well Levels, Aeration and Treatment Unit Levels
Loss-of-Head and Rate-of-Flow Gauges — Filter Effluent
Model DVSX-A Chlorinizer arranged for proportional control — Raw Water and Industrial Water Supply
Model DVSX-M Chlorinizers manually operated — Post-Chlorination
Instrument Panel
Semi-Automatic Filter Backwash Controls

[illegible] new and advanced type of purification unit to perform these functions. Four circular Aldrich-design purification units, in place of conventional filters and basins, are proving their effectiveness by adequately serving the water needs of a population of 100,000. The new plant is under the direction of J. L. Matthews, Mgr.

B-I-F Industries Equipment is serving in every phase of this interesting new plant. Omega Chemical Feeders deliver the dry chemicals required by the treatment process. Builders Instruments and Remote-Automatic Controls assist in making this a one-man-per-shift operation. Finally, gas chlorine for sterilization of finished water is controlled by Builders modern, full vacuum Chlorinizers. For Bulletins describing B-I-F Industries Equipment, address B-I-F Industries, Providence 1, R. I.

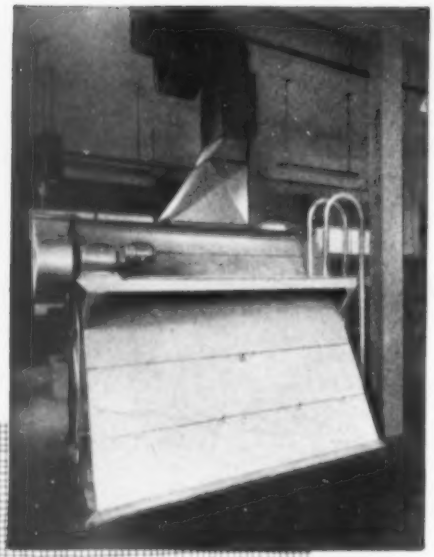
BUILDERS

B-I-F INDUSTRIES

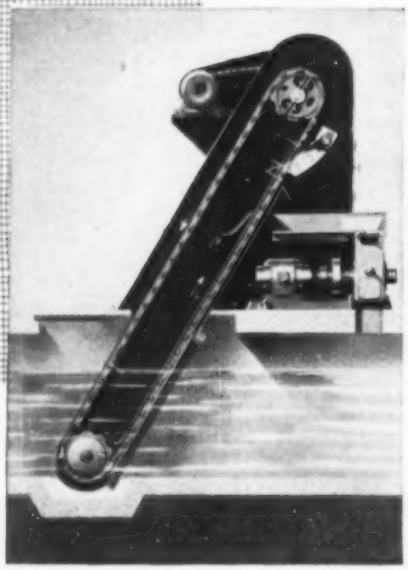
OMEGA

220 Cities can't be wrong!

REX FRONT CLEANED BAR SCREENS ARE BEST



because



Yes, 220 cities with over 300 installations offer proof of the leadership of Rex Front Cleaned Bar Screens. For over 20 years Rex Screens have been satisfying customers throughout the United States and in many foreign cities. Here are some of the outstanding proven features of Rex Screens that make them leaders in their field.

- **Streamlined Construction**—unobstructed flow to rack-guarded chain—streamlined sprockets.
- **Rigidly Fastened Bar Rack**—bars accurately spaced—no obstructing cross members.
- **Solid Plate Rake** with machined teeth for positive cleaning of bar rack and greater capacity.
- **Positive Rake Wiping**—quiet—adjustable—prevents screenings carry-over to downstream side.
- **Rex Z-Metal Chain** and attachments—corrosion and wear resisting.
- **Split Head Sprockets**—easily removable.
- **Efficient Drive Unit**—fully enclosed—shear pin protection against overload.
- **Fully Enclosed Screen**—rugged design—neat appearance—easy removal of screenings.
- **Low Cost**—original operating—maintenance.

Your Rex District Sales Engineer can give you the details on all of the advantages of Rex Front Cleaned Bar Screens. Call him today, or if you prefer, write to Chain Belt Company, 4610 W. Greenfield Avenue, Milwaukee 1, Wisconsin.

CHAIN BELT REX COMPANY

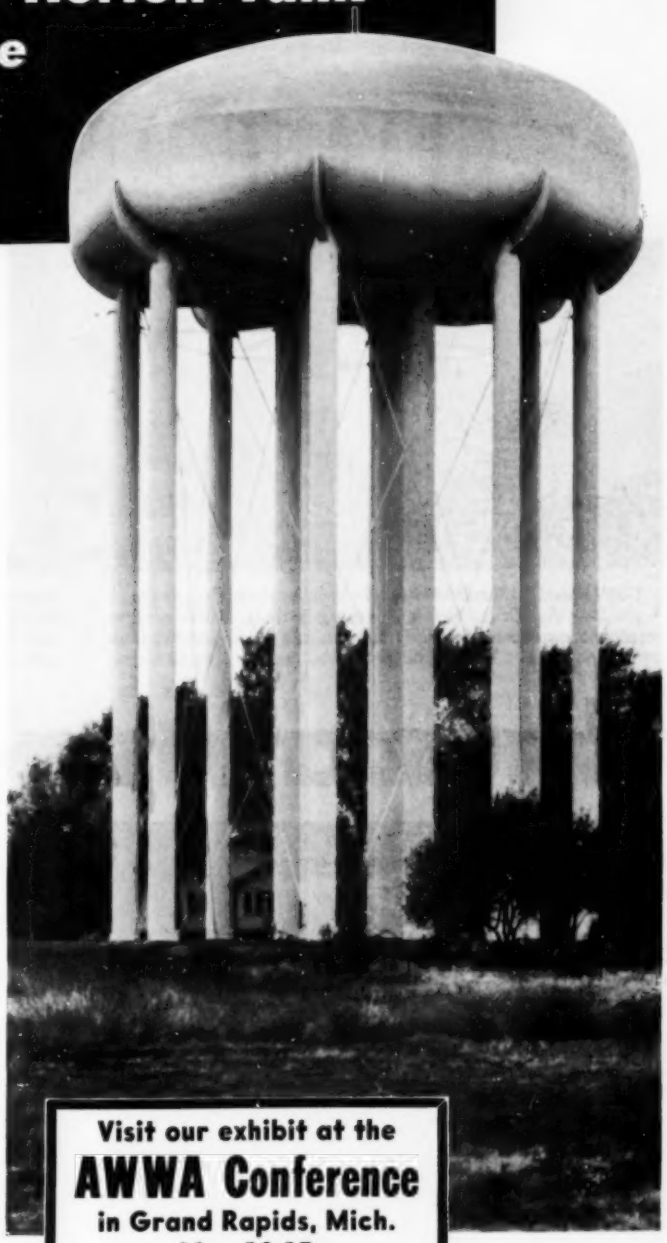
Chain Belt COMPANY OF MILWAUKEE

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Cleveland • Dallas Denver • Detroit • El Paso • Houston • Indianapolis • Jacksonville • Kansas City • Los Angeles • Louisville Midland, Texas • Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh • Portland, Ore. Springfield, Mass. • St. Louis • Salt Lake City • San Francisco • Seattle • Tulsa • Worcester

Distributors located in principal cities in the United States and throughout the world

EXPORT OFFICES: Milwaukee and 19 Rector Street, New York City.

1,000,000-gal. Horton Tank *reduces pressure variations at Streator*



After Horton radial-cone elevated tank was installed . . .

- Minimum pressures were increased to 58 lbs. per sq. in.
- Pressure variations were reduced to 6 lbs. per sq. in.

Horton radial-cone tanks for municipal water service, like the one at Streator, Illinois, are built in standard capacities from 500,000 to 3,000,000 gallons—and tanks with ellipsoidal-bottoms are available in standard sizes from 15,000 to 500,000 gallons. For estimates or quotations, please write our nearest office.

Visit our exhibit at the

AWWA Conference

in Grand Rapids, Mich.

May 10-15

Booths 98-99

HORTON

WELDED STEEL

STORAGE TANKS

CHICAGO BRIDGE & IRON COMPANY

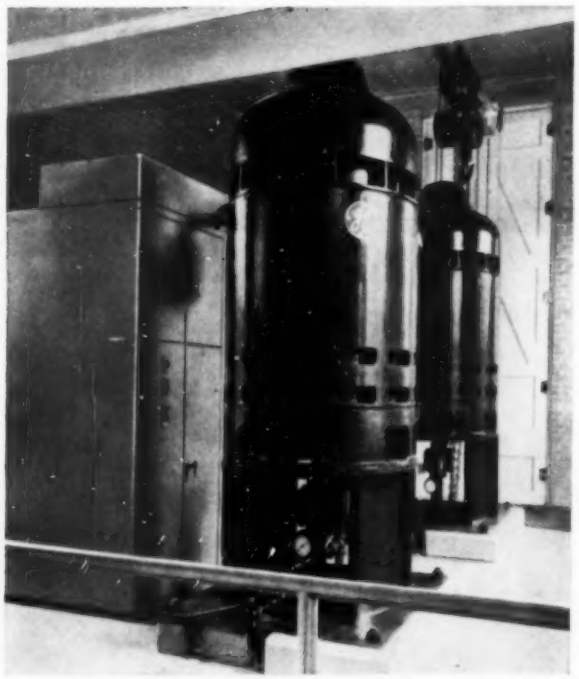
Plants in Birmingham, Chicago, Salt Lake City, and Greenville, Pa.

Atlanta 3	2181 Healey Bldg.	Houston 2	2115 C. & I. Life Bldg.
Birmingham 1	1586 North Fiftieth St.	Los Angeles 17	1555 General Petroleum Bldg.
Boston 10	1018—201 Devonshire St.	New York 6	3390—165 Broadway Bldg.
Chicago 4	2198 McCormick Bldg.	Philadelphia 3	1644—1700 Walnut Street Bldg.
Cleveland 15	2262 Midland Bldg.	San Francisco 4	1583—200 Bush St.
Detroit 26	1551 Lafayette Bldg.	Seattle 1	1350 Henry Bldg.
Havana	402 Abreu Bldg.	Tulsa 3	1646 Hunt Bldg.

1 SUBURBAN PHILADELPHIA. Here, in modernizing and expanding the Crum Creek Pumping Station, steam equipment was replaced with G-E motors and power-distribution equipment. As a result, output was increased by 5 mgd, operating efficiency improved by 20 per cent. Photo shows two G-E motors, rated 900 hp and 200 hp driving 15-mgd and 3-mgd DeLaval pumps. Latter is one of two. Motors are controlled from G-E metal-clad switchgear in rear.

Three cities act now for

3 WINSTON-SALEM, N. C. Recent expansion has increased pumping capacity at High Service Station by 12 mgd. Shown are two of seven G-E motors, protected by G-E Limitamp control, which account for new 29½-mgd capacity.



At the Yadkin River Pumping Station, these G-E 600-hp vertical motors, controlled by G-E Limitamp panels, drive 4-mgd Worthington pumps. Consultants were J. D. Spinks of Winston-Salem and Albright & Friel of Philadelphia.

2 LA GRANGE, GA. This new water-treatment plant has a 4-mgd capacity. Only 68 per cent loaded, it will meet the city's needs till 1960. Plant and pump house operations are controlled by one man from this G-E Cabinetrol* control unit.

Incoming power for plant is stepped down by three G-E 150-kva transformers. G-E engineers worked closely with Wiedeman & Singleton, consultants, J. H. Small & Co., contractors, and White Electrical Constr. Co., electrical contractors.

more water tomorrow

Install new G-E equipment to boost efficiency, meet present and future needs for greater capacity

These three cities—suburban Philadelphia, La Grange, Ga., and Winston-Salem, N.C.—are typical of many others throughout the nation that realize action is needed, and needed now, to prevent serious water-supply problems in the future.

In each case, whether it involved an entirely new installation or a modernization and expansion program, their objective was the same—to provide efficient increased capacity for today and tomorrow, to match the needs of a growing population, greater per-capita water consumption, and industrial expansion.

In each case, too, General Electric equipment was chosen for the electrical system, and G-E engineers offered valuable assistance on electrical system planning to municipal engineers and their consultants.

*Registered Trade-mark of General Electric Company.

This same kind of help can pay off for *your community's* water-supply program, too. G-E application engineers are ready to work closely with your engineers or consultants in developing a co-ordinated electrical system to meet your community's requirements. For best results, call in your G-E Apparatus Sales representative early in the planning stage.

MAKE YOUR COMMUNITY WATER-SUPPLY CONSCIOUS

Dramatize the need for an adequate water supply by showing the new color movie "Pipeline to the Clouds." It's part of G.E.'s *More Power to America* Water Supply Program. Contact your local G-E Apparatus Sales Office or write on your letterhead for Bulletin GEA-5555 to General Electric Co., Section 666-74, Schenectady 5, N. Y.

Engineered Electrical Systems for Waterworks

GENERAL ELECTRIC

Part of a 13 mile installation of "Century" Asbestos-Cement Pipe, Lakewood Water District, near Tacoma, Washington

Stock of "Century" Asbestos-Cement Pipe .

Water carried 13 trouble-free miles through "CENTURY" asbestos-cement pipe

Near Tacoma, Washington, the Lakewood Water District which serves a very fine residential area recently completed a "Century" Asbestos-Cement water main that will please the taxpayers . . . for generations. For this intimately compacted mixture of two practically indestructible materials—asbestos fiber and portland cement—is so economical to install and so trouble-free in operation that today's money-raising problems are solved, and tomorrow's performance promises kept.

From shipment . . . through piling on the job . . . to eventual cutting-in, this light, exceptionally strong pipe, moderate in cost, is easy to handle. With "Century" Simplex Couplings, curves up to 5° deflection per pipe length can be laid as simply as straight runs, flexural strains caused by earth settlement or trench loading are minimized, and special bends held to a minimum. Labor savings all along the line result.

The economy and complete satisfaction that begin with installation continue down through the years with "Century" Asbestos-Cement Pipe. Because it never tuberculates, its smooth inner surface is permanent, assuring continuous flow with minimum pumping costs. Its outer surface is highly resistant to the corrosive effects of any soil.

Whether or not you are presently planning to buy or specify pipe for water mains, learn more about "Century" Asbestos-Cement Pipe.

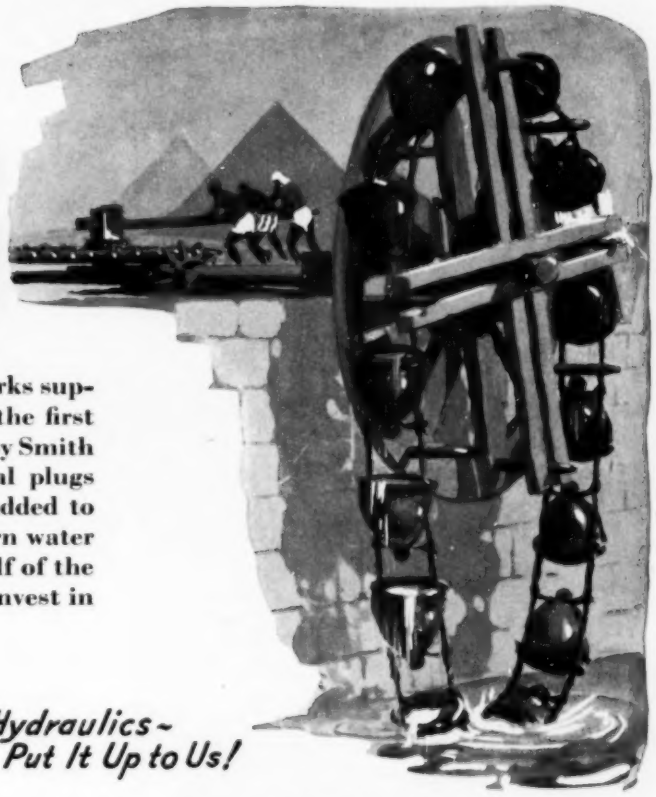
Write for
FREE BOOKLET,
"Mains without Maintenance". Gives valuable data, specifications, and reference material for anyone interested in water main pipes.

Nature made Asbestos . . .
Keasbey & Mattison has made it serve mankind since 1873

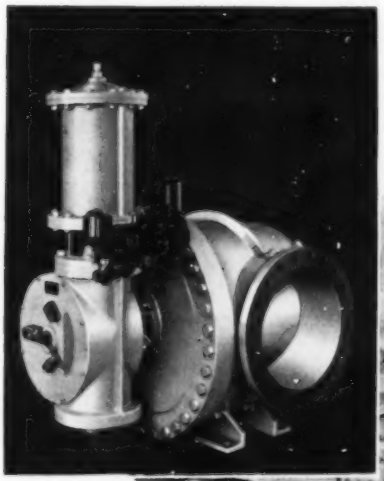
K&M
Well in asbestos
®

KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

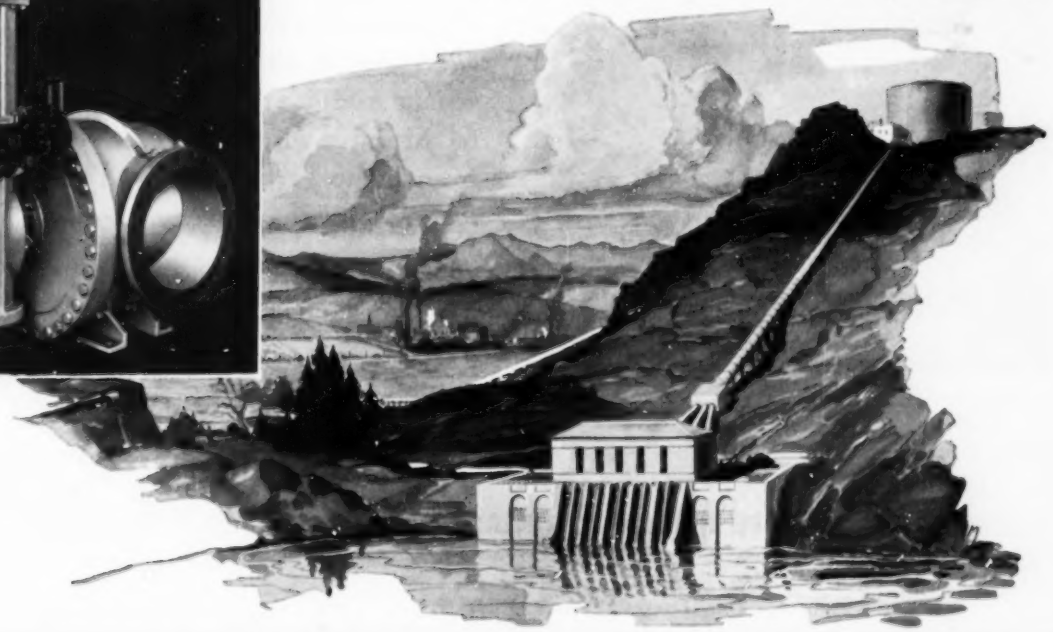
Modern WATERWORKS *possible with* Rotovalves *by* SMITH



MOVING ever onward, the huge water works supply systems of today have evolved from the first crude inventions of antiquity! Rotovalves by Smith with their full circular openings, conical plugs and electrically welded seat rings have added to the efficiency and reliability of the modern water works and sewage systems. Assure yourself of the utmost return on your Valve Dollar and invest in Rotovalves. Write for our bulletin.

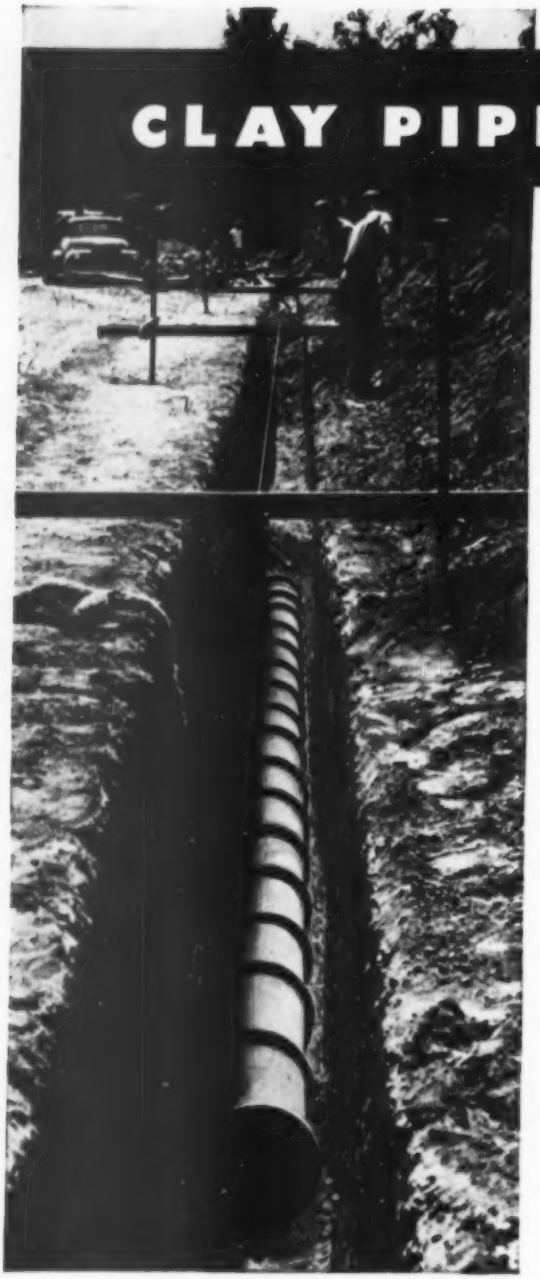


If It's Hydraulics - Put It Up to Us!



S. MORGAN SMITH Co.

YORK. PENNA. U.S.A.



CLAY PIPE *Specified*

For New Tuscaloosa Municipal Sewer Project

More than 44,000 feet of Vitrified Clay Pipe are being installed to serve a growing residential area in Tuscaloosa, home of the University of Alabama.

Because Clay Pipe proved outstanding over the years in Tuscaloosa sewerage installations, it was again first choice for the current $170,000 sewer expansion program. City engineers throughout the country rely on the dependability and proven performance of Vitrified Clay Pipe for sanitary sewers. It's guaranteed for 50 years!

Clay Pipe is readily available, too. It's *all* clay — an abundant, non-critical material. And it's chemically inert, unaffected by acids, detergents, or wastes from home garbage disposal units. It's the one pipe that *never wears out!*

Vitrified

CLAY

CLAY PIPE NEVER WEARS OUT!

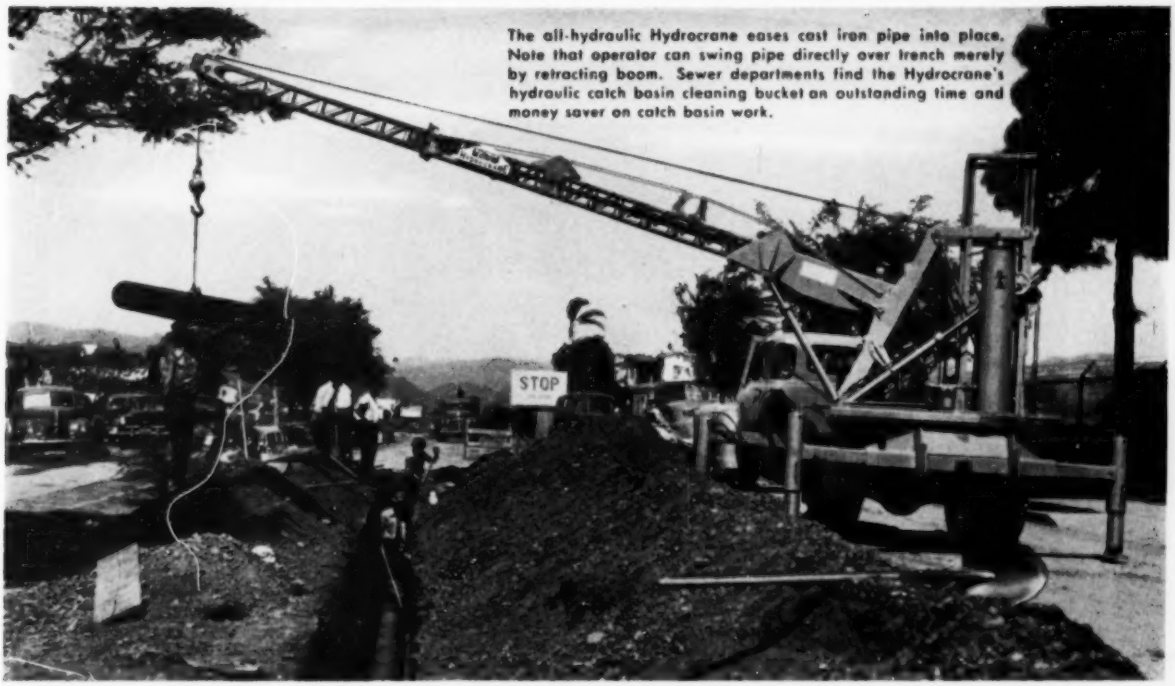
PIPE

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1520 18th St. N. W., Washington 6, D. C.
206 Connally Bldg., Atlanta 3, Ga.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio

ESSENTIAL • ECONOMICAL • EVERLASTING

C 253-5



The all-hydraulic Hydrocrane eases cast iron pipe into place. Note that operator can swing pipe directly over trench merely by retracting boom. Sewer departments find the Hydrocrane's hydraulic catch basin cleaning bucket an outstanding time and money saver on catch basin work.

HYDROCRANE'S built-in reach cuts down the "extra-cost" jobs

Bucyrus-Erie's ⅜-yd. Hydrocrane with hydraulically telescoping boom gives you 8 ft. more boom — right at your fingertips. This special extend-retract action means substantial savings on ordinary jobs . . . outstanding savings on the tough extra-cost jobs outfits with ordinary booms can't handle. Look:

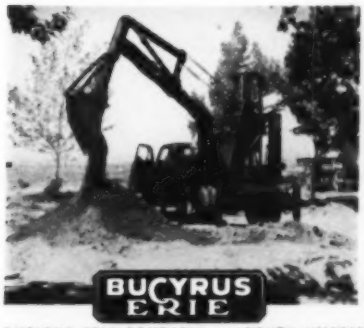
1. *On sewer and water pipe laying, hydrant and valve setting,* the Hydrocrane reaches under branches and low overpasses, between buildings, into alleyways — eases units into place quickly, easily.
2. *On excavating work,* the Hydrocrane digs trenches and manholes, uncovers pipe leaks, handles dozens of digging jobs — often *by reaching out* while the crane itself stays out of the way of traffic.
3. *On yard work* reaches into box cars . . . over fences . . . between stockpiles to move material, load trucks — in a hurry.

quick convertibility to *HYDROHOE*

By actual stop-watch test, crane has been converted to dragshovel front end by one man in *less than one hour!* And on trenching, telescoping action of Hydrohoe boom cuts lost time moving up by as much as 40 percent.

Get the full story on the all-hydraulic Hydrocrane with its many attachments.

SEND COUPON TODAY . . .



Trench cut is started with the Hydrohoe. Available with either 12- or 18-inch dipper — equipped with hydraulic ejector that kicks dirt out.

BUCYRUS-ERIE COMPANY • SOUTH MILWAUKEE, WISCONSIN

BUCYRUS-ERIE COMPANY
South Milwaukee, Wisconsin

Gentlemen: ☐ Please send me Hydrocrane literature.
☐ Please send me Hydrohoe literature.

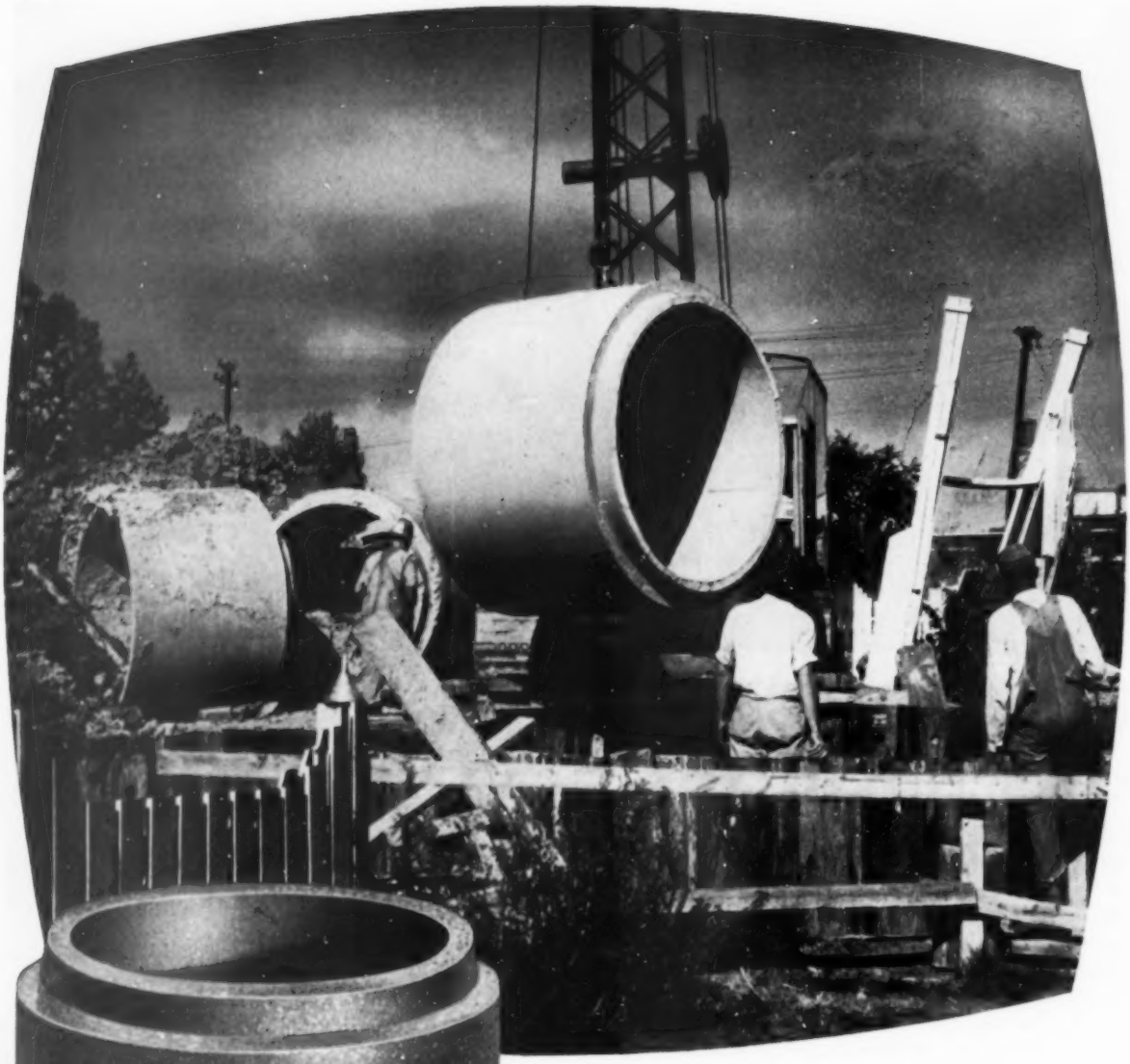
Name.....

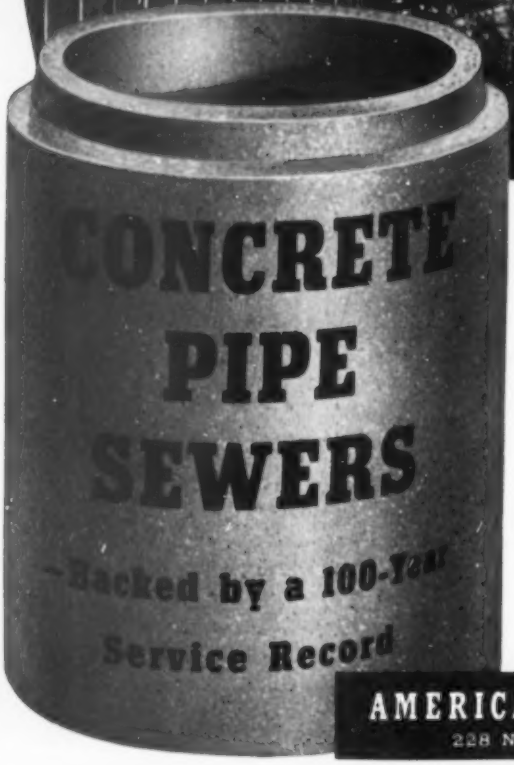
Title.....

Address.....

City..... State.....

15H53





For more than 100 years, sanitary engineers have specified concrete pipe for all types of sewers. This long usage of concrete pipe is due to the fact that it meets these essential requirements:

1. **GREAT STRENGTH** to resist severe impact and to sustain the heavy overburdens of deep fills.
2. **MAXIMUM CAPACITY** due to smooth interior finish and clean, even joints.
3. **MINIMUM INFILTRATION AND LEAKAGE** because of uniformly dense structure and tight joints.
4. **DURABILITY** that enables it to render long years of heavy-duty service.
5. **ECONOMY** that results from moderate first cost, low maintenance expense and extra long service.

AMERICAN CONCRETE PIPE ASSOCIATION
228 NORTH LA SALLE STREET, CHICAGO 1, ILLINOIS

REPLACE troublesome VALVES With . . .

EDDY MECHANICAL JOINT GATE VALVES

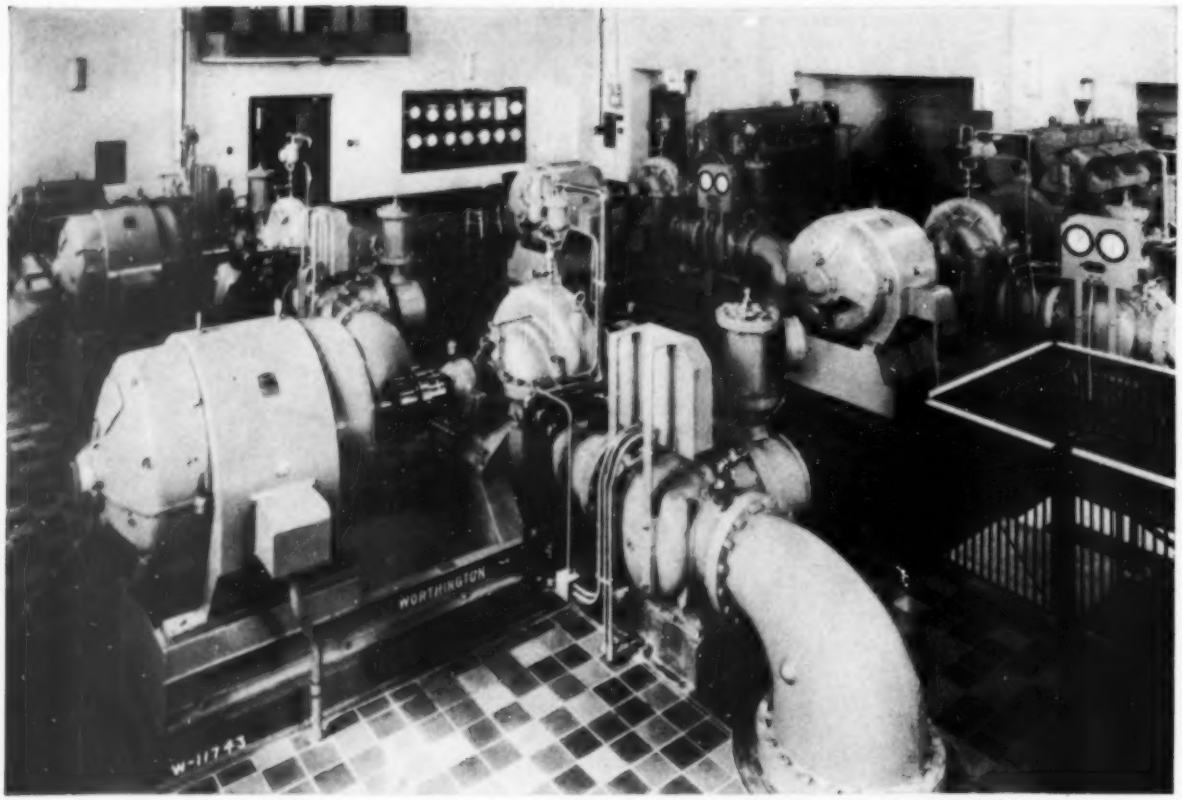
Old and troublesome valves . . . or too few valves in a distribution system . . . can be responsible for dangerous and costly slow-down or shut-down of water supply for every day use or, more serious, when badly needed in event of an emergency. Now is the time to make replacements and to install new valves where conditions show the need for so doing. The Eddy Valve, bronze mounted throughout, with mechanical joint connections (only a ratchet wrench needed) is best for easy installation . . . for easy operation . . . for long life trouble-free service.

•

Write today
for prices and delivery date for valves needed to modernize your water distribution system.

EDDY
VALVE COMPANY
WATERFORD, NEW YORK

A subsidiary of James B. Clow & Sons



AS MODERN AS YOU'LL SEE ANYWHERE is this clean tile brick pump building at Evanston, Illinois, Water Works. At the left are three High Lift pumps—6-mgd, 8-mgd and 15-mgd—driven by Electric Machinery motors. At right are two 10-mgd High Lift pumps dual-driven by 350-hp E.M. motors and gasoline engines. Three other 125-hp Wash Water pumps are not shown.

Evanston Water Works– First on the North Shore– boasts modern Worthington-equipped pump room

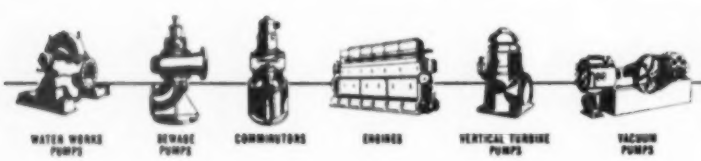
In the 1890's, it was Evanston, Illinois, that set the pace in water works facilities along the North Shore with the first filtration plant.

Today, this famous midwest city is still known by municipal engineers everywhere for its modern and efficient water-supply installation. The pump room pictured here is a vital part of these facilities.

Built in 1949, the new building houses eight motor-driven Worthington centrifugal pumps including three 10-mgd Wash Water pumps and three High Lift pumps—one 15-mgd, one 8-mgd and one 6-mgd. Two 10-mgd High Lift pumps are dual-driven. The complete water works installation was engineered by Alvord, Burdick and Howson of Chicago, Illinois, Consulting Engineers.

You'd naturally expect cities like Evanston, with reputations for the best in water works facilities, to demand the best in pumping equipment. Their choice is proof that *there's more worth in Worthington.*

WORTHINGTON CORPORATION,
Public Works Division, Harrison, New Jersey. W-2.1



WORTHINGTON

Public Works Equipment

All Major Public Works Equipment Under One Responsibility

IT'S DARLING'S NEW

B-50-B

Patent Pending

FIRE HYDRANT

...What a difference!

YES, what a *difference!* That's the word that's going around about the new and unique B-50-B—rated the most important advance in fire hydrant design in 50 years.

First, note that the B-50-B is *ball bearing* operated. Opening and closing takes less than half the usual wrench torque. *Smoother, faster, easier* operation every time!

Next, see how the B-50-B design uses "O" ring seals. No need for a stuffing box. It's a packless, *dry-top* hydrant. And it saves plenty of time and trouble! Does away with bothersome packing gland adjustment as well as the usual lubrication and maintenance of packing. Moreover, this "O" ring arrangement not only prevents the loss of thread and bearing lubricant, but never lets a drop of water reach the operating threads. Just add up *these* advantages!

As in any Darling hydrant, all inside working parts (main valve, main valve seat, drain valves and drain valve seats) can be removed through the top of the B-50-B for easy inspection and simplified maintenance. One 15-pound wrench does the trick, regardless of trench depth.

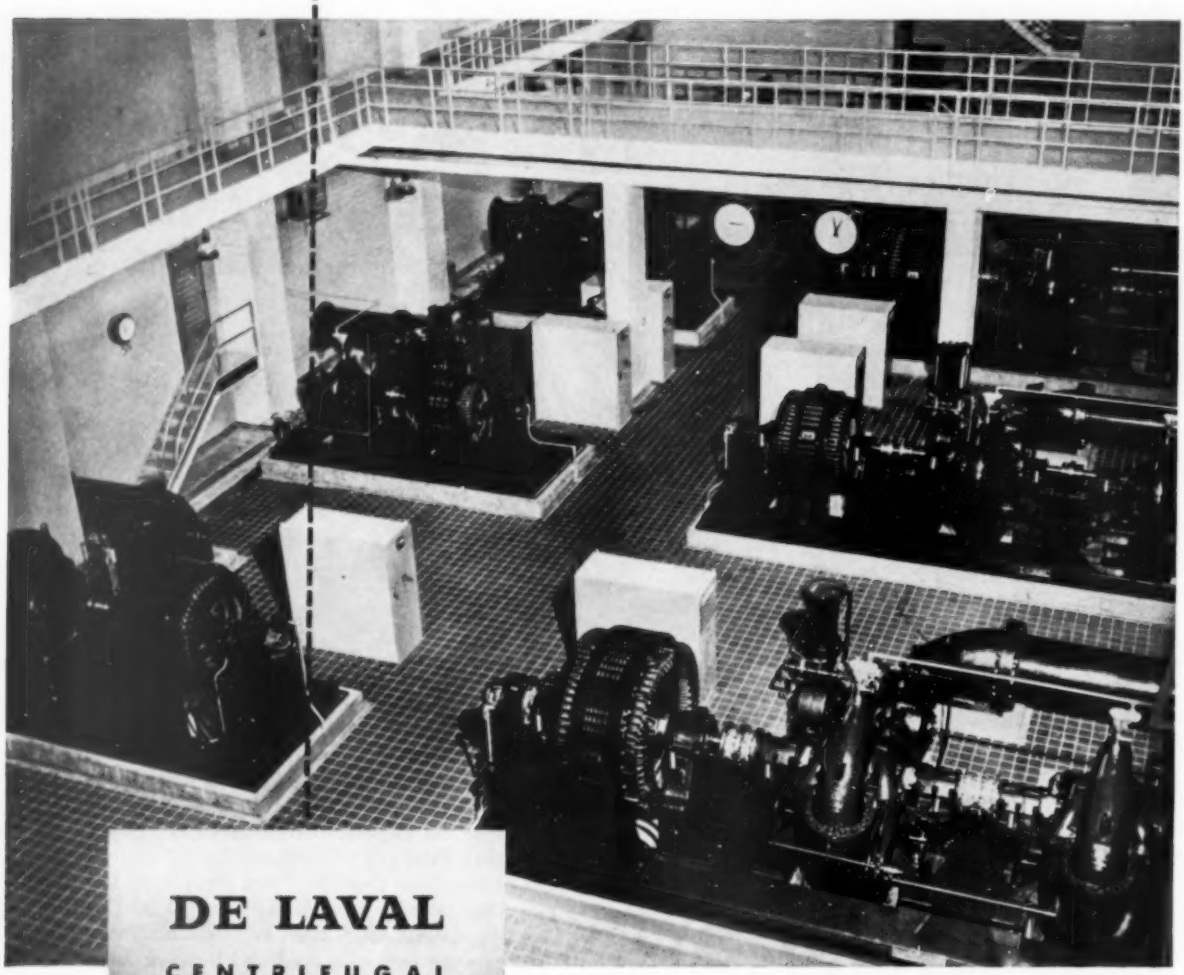
Before you decide on *any* hydrant, get *all* the facts on the Darling B-50-B.

Write for Bulletin No. 5007

DARLING VALVE & MANUFACTURING CO.

Williamsport 11 Pa.

Delivering 172 mgd more for Cleveland



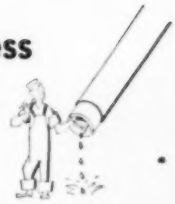
These new De Laval centrifugal pumps in the Nottingham filtration plant help deliver an additional 172,000,000 gallons of filtered water daily to Cleveland's growing population. Today 80% of America's largest cities depend upon efficient De Laval centrifugal pumps. They are available in capacities ranging from less than one million gallons per day to more than 100 million gallons per day.

Write for Catalog 83-29R giving complete data.

DE LAVAL *Centrifugal Pumps*

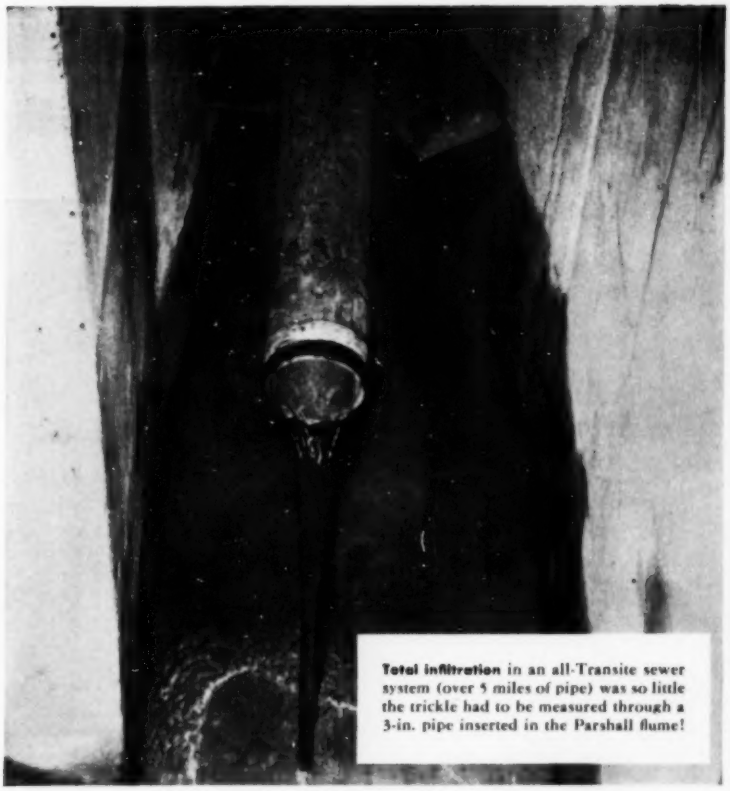
DE LAVAL STEAM TURBINE COMPANY
824 Nottingham Way, Trenton 2, New Jersey

You'll have less infiltration . . .



reduce treatment costs . . .

conserve plant capacity . . .



Total infiltration in an all-Transite sewer system (over 5 miles of pipe) was so little the trickle had to be measured through a 3-in. pipe inserted in the Parshall flume!

—ALL because of this RING-TITE JOINT used with Transite Sewer Pipe

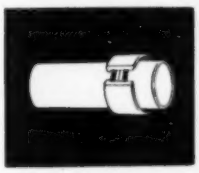
THE reduction of ground-water infiltration brought about by the Ring-Tite® Joint—now standard on all sizes of Transite® Sewer Pipe—can lead to a number of cost-saving results.

For example, on one recently installed Ring-Tite System using 28,540 feet of Transite Sewer Pipe, in diameters of 6 through 18 inches, the infiltration per inch of diameter, per hour, per mile of pipe came to a mere 0.85 gal. This low infiltration (including that from manholes and connections to house sewers) was achieved despite the fact that a considerable portion of this installation was below the prevailing ground water table. (For specification purposes, an infiltration allowance of 10 gallons per inch of diameter, per hour, per mile of pipe may be used with Transite Sewer Pipe.)

Obviously, such minimum ground-water infiltration helps reduce the load on treatment plants, cuts down on treatment costs, and conserves plant capacity for future expansion needs. This reduced infiltration plus Transite's high flow capacity (Manning's N=.010) often permits the use of smaller diameter pipe for new installations.

For further information on how this Ring-Tite Joint, used with corrosion resistant asbestos-cement Transite Pipe can help reduce your sewage costs, write Johns-Manville, Box 60, New York 16, N. Y. Ask for folder TR-103A.

Why the RING-TITE JOINT cuts your sewage costs



Two rubber rings and Transite Sleeve (cutaway) can be assembled quickly over Transite Pipe ends to make a pressure-tight joint. These flexible joints effectively absorb vibration, help compensate for soil movements.

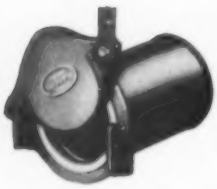
TIGHT ALL THE WAY

Johns-Manville Transite Building Sewer Pipe assures a tight sewer system throughout. Many municipal officials are insisting that house and building connections to their sewage lines be made with Johns-Manville Building Sewer Pipe to assure tightness throughout their systems. This pipe also has the rubber ring sealed joint that is shown above.

Johns-Manville TRANSITE SEWER PIPE

PROVED IN THE PAST... FIT FOR THE FUTURE

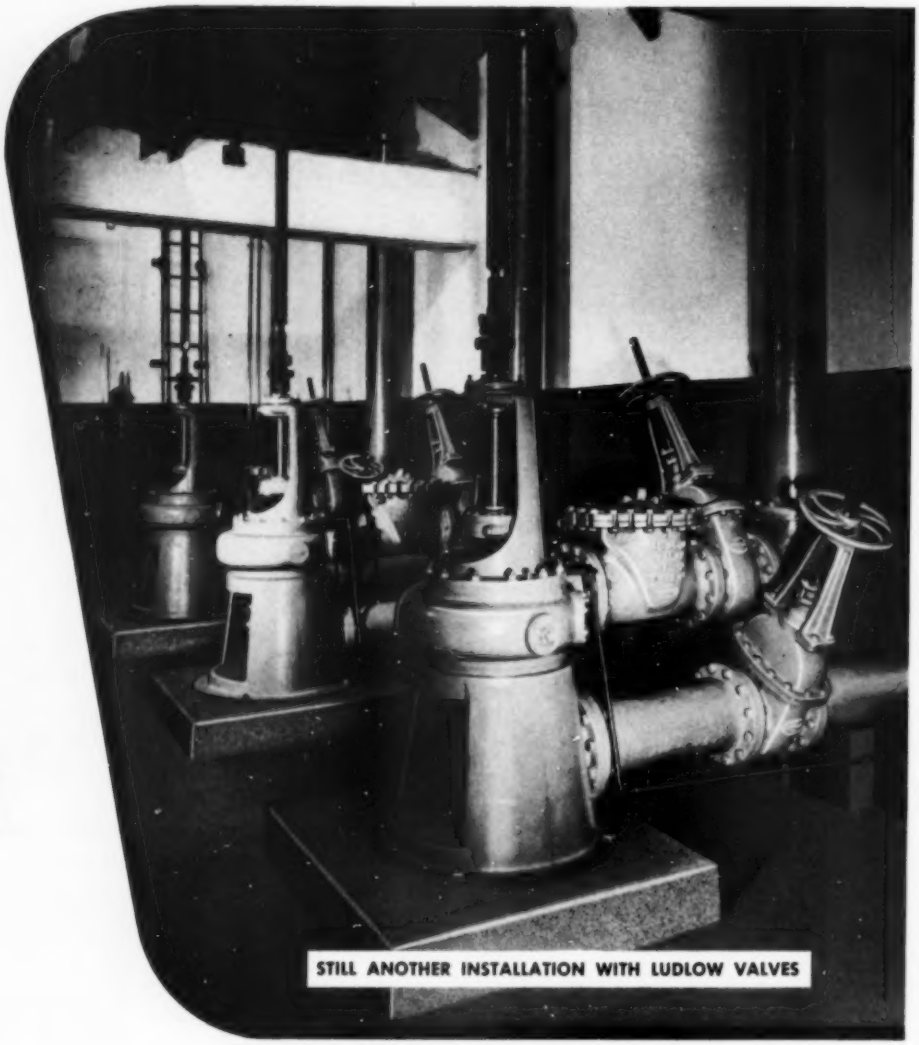
SLUICE GATES



SHEAR GATES

FLAP VALVES

MUD VALVES



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The HERSEY COMPOUND METER

has <u>proven</u> itself superior in every way for long life and accurate registration of all rates of flow.

A Hersey Creation that has never been equaled

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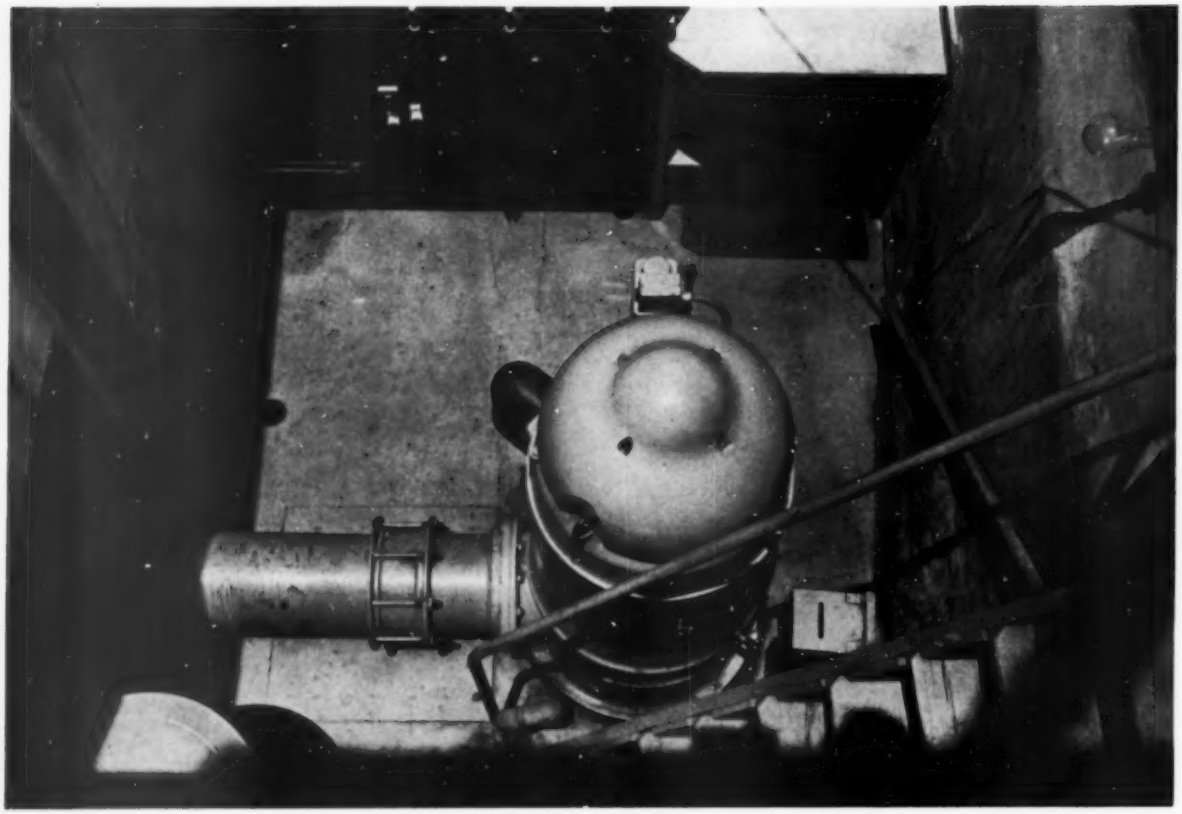

TAKE THIS MUNICIPAL PUMPING STATION, FOR EXAMPLE...

Over 40 years ago, the Sunnyslope Water Company of Pasadena, California installed their first Johnston Vertical Turbine Pump. Since then Sunnyslope has used Johnston equipment exclusively. There must be reasons for this kind of product acceptance. Here are a few...

Vertical design saves as much as 60% floor space, to say nothing of head room.

Johnston Pumps need no priming—so can be installed to start and stop automatically, without expensive priming devices.

Johnston Pumps are tough... They require practically no maintenance... and they'll handle jobs other pumps can't touch.

Johnston Pumps are the cheapest pumps you can buy per year of service. Case histories prove it!

This is another example of the ability of Johnston equipment to handle all types of pumping jobs. Why not let our engineers consult with you on *your* special problem.

Send for free booklet about Johnston Pumps. Ask for Bulletin K-53

JOHNSTON PUMP COMPANY

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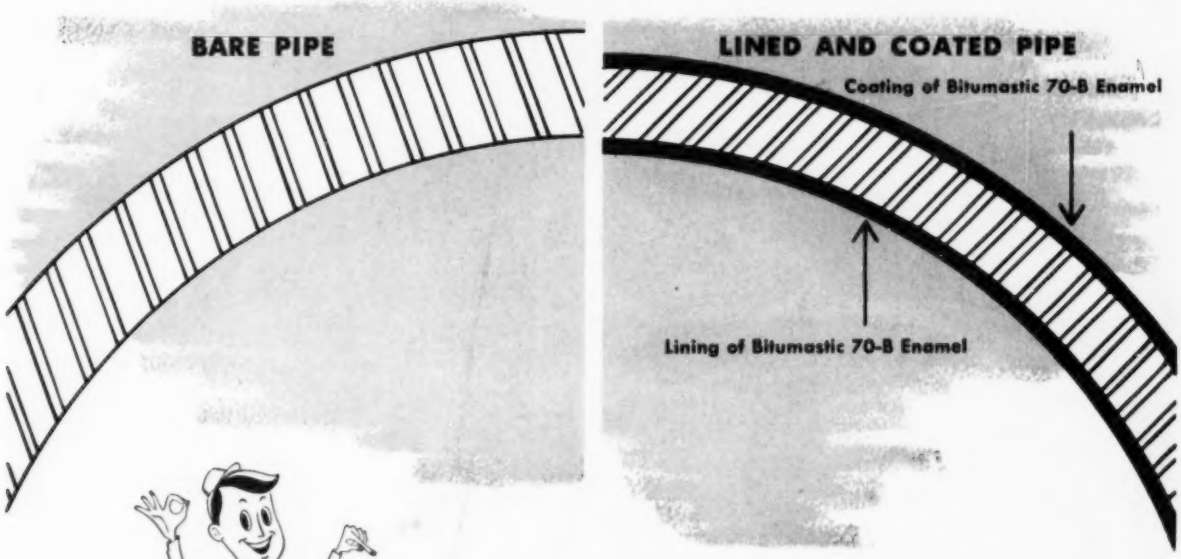
Yes—you can specify steel pipe —with less wall thickness



. . . when you protect it with BITUMASTIC® 70-B ENAMEL

BITUMASTIC 70-B Enamel—when applied to a thickness of 3/32"—protects the exterior of pipe from the corrosive action of the soil in which it is buried. It is much more economical to use this protective coating than to specify pipe with greater wall thickness in order to allow for future corrosion.

For instance, if it were calculated that a 3/8" wall would provide sufficient structural strength for a given pipe line, it would be unnecessary to specify a 7/8" wall to compensate for corrosion. The use of Bitumastic 70-B Enamel would do away with the need for the additional 1/4" of steel—a substantial saving.

Besides specifying less wall thickness, you can use *smaller* pipe by applying Bitumastic 70-B Enamel. A spun lining of this enamel *keeps* flow capacity high. So you don't have to buy *over-sized* pipe to allow for future "shrinkage."

Give your community this two-way savings on your large-diameter water lines by specifying strong, durable steel pipe, lined and coated with Bitumastic 70-B Enamel. If you wish, we will handle the entire coating job for you. Write for full information.

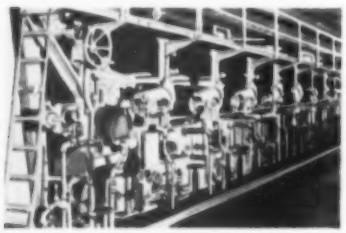
KOPPERS BITUMASTIC ENAMELS

KOPPERS COMPANY, INC., Tar Products Division, Dept. 561-T, Pittsburgh 19, Pa.

DISTRICT OFFICES: BOSTON, CHICAGO, LOS ANGELES, NEW YORK, PITTSBURGH, AND WOODWARD, ALA.

CELITE FILTRATION controls water purity— removes *all* suspended solids

In oil wells—output is boosted by repressurizing wells with water to force out accumulated oil. Celite Filtration purifies water to the extreme degree required—removes the minute suspended impurities which would otherwise clog the microscopic pores of sandstone.



In paper plants—Celite Filtration is used to purify the large quantities of water used in paper formation. Waste water may be filtered for reuse by the same process. Celite filter cakes can withstand many times the pressure of an ordinary filter bed. No pH control is necessary with Celite. *T.M. Reg. U.S. Pat. Off.

CELITE* FILTRATION provides the *right degree* of purity that you require for industrial process water. It removes sediment which may cause costly downtime or damage to expensive plant equipment. And if your application requires greater purity, Celite removes even such fine suspended solids as amoebae and algae, many of which cannot be filtered out by other methods. Moreover, fast, economical rates of flow can be maintained with Celite Filtration.

This selectivity in degree of water purity is made possible because Celite comes in nine standard grades . . . each designed to filter out impurities of specific size and type. Carefully processed from the purest deposits of diatomaceous earth, Celite always has utmost uniformity of product. Whenever you reorder, you are assured of the same accurately graded powder.

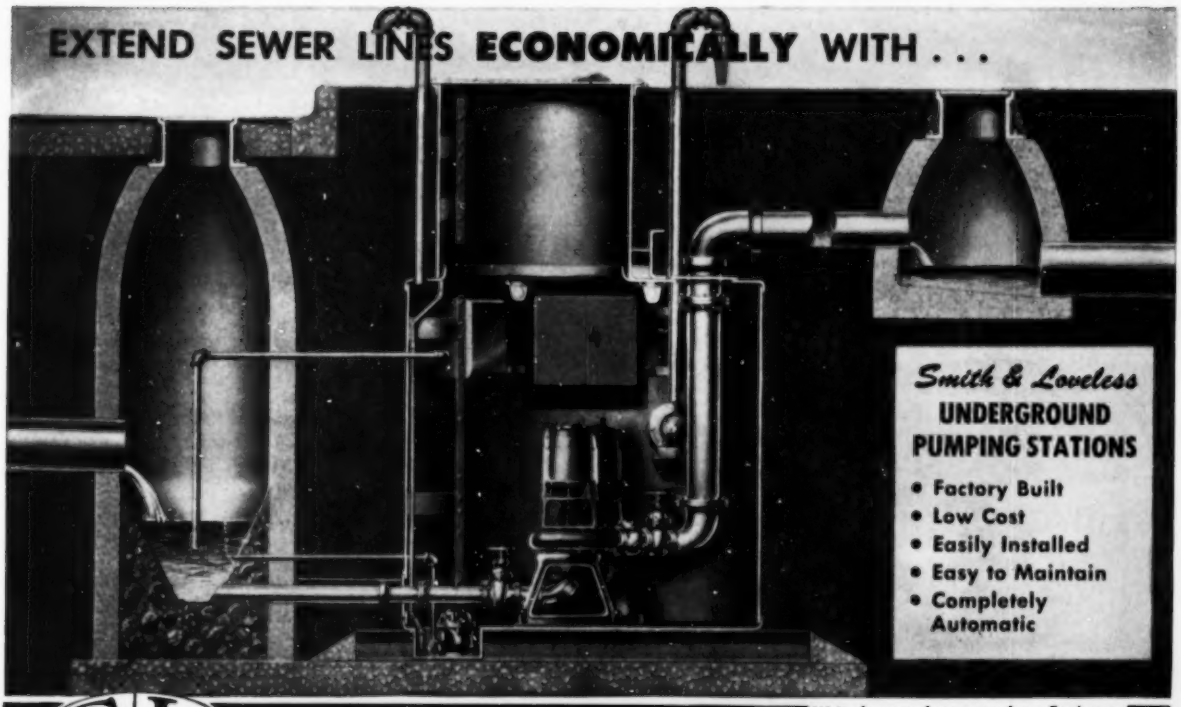
Celite Filtration offers many other advantages, too Important space savings are achieved in the installation, longer filtration cycles are obtained, and less backwash water is required for cleaning the filters than with ordinary systems.

Celite Filtration provides pure process water for boiler make-up, heat exchangers, circulating water for towers . . . and many other industrial uses. It will pay you to investigate the advantages of Celite for your particular application. To have a Celite engineer study your problem and offer recommendations, simply write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville CELITE FILTER AIDS

EXTEND SEWER LINES ECONOMICALLY WITH . . .



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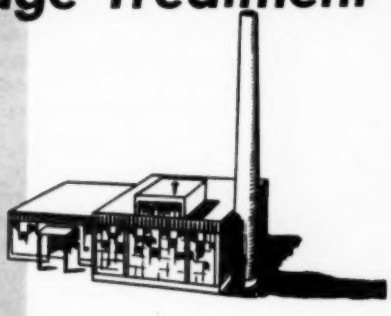
How to . . *Streamline Sewage Treatment*



Dry and/or Burn Sludge with Nichols Multiple Hearth dryer-incinerators. Burn sewage sludge to a sterile ash or dry it for use as a fertilizer.

Use Proved Adaptable Equipment . . . the Nichols Multiple Hearth furnace, successfully incinerates sludge in liquid, thickened, raw or digested state. Assures simple, positive, dependable and economical sludge disposal.

Have a Compact, Attractive Plant such as is made possible by use of the Nichols Multiple Hearth Dryer-Incinerator. Unsightly, space-wasting sludge beds, lagoons, dumps and digesters can be eliminated.

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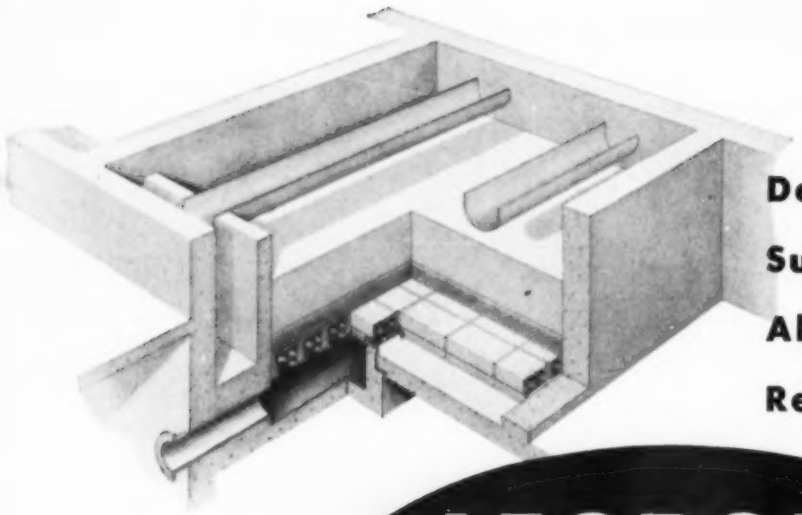

Filter Unit Showing installation of Leopold Glazed Tile Filter Bottom

Designed to Successfully Meet All Underdrain Requirements...

LEOPOLD
Glazed Fire Clay
TILE FILTER BOTTOMS

Performance Proved in Over 200 Plants with a Daily Capacity of More Than 900 Million Gallons!

With its many exclusive advantages, the Leopold Compound Duplex Filter Bottom provides the most practical and economical answer to your underdrain problems.

In this design, laterals and distributing blocks are combined in one permanent unit that insures uniform filtration over the entire filter bed and equal distribution of the wash water with minimum loss of head. The individual blocks—each about two square feet in area and weighing approximately 100 pounds—are made of highest quality de-aired fire clay, vitrified and salt glazed. They resist corrosion, are not subject to tuberculation, won't absorb any detrimental amount of water, and are impervious to acids and alkalis.

Adaptable to any rectangular filter unit, the efficient Leopold Filter Bottom needs only a shallow depth of small sized filter gravel to support the filtering medium. Further, the Leopold design does not require special supporting concrete members or the added concrete construction of a false bottom.

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F. B. LEOPOLD CO., INC.

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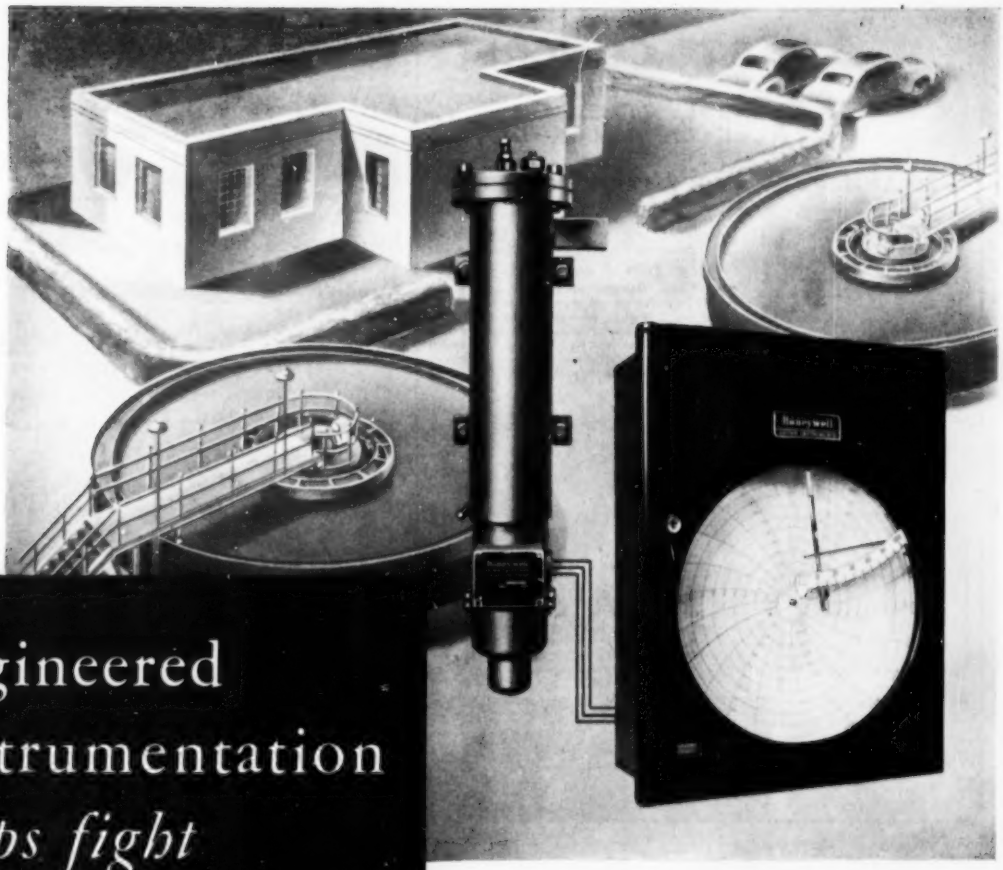
COMPLETE WATER PURIFICATION and SEWAGE PLANT EQUIPMENT
DRY CHEMICAL FEEDERS · FILTER OPERATING TABLES · MIXING EQUIPMENT



engineered instrumentation *helps fight stream pollution*

PLAN FLOW INSTRUMENTATION FOR THE FUTURE *—by selecting the Brown Evenly Graduated Flow Meter. This instrument provides accurate measurement at fractional-scale readings—gives full precision when your plant is running at part load, and after it has grown to final capacity.*

WHEREVER your waste treatment plant needs to measure and totalize flow—of plant influents, effluents, filter backwash water, gas, carbon dioxide, and numerous other fluids—you'll find the Brown Evenly Graduated Flow Meter the ideal solution to your problems.

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The Brown Flow Meter embodies simple, rugged construction in every detail. The meter body is corrosion resistant, light-weight and sturdy. And to assure you of continuous performance, Honeywell's widespread organization offers prompt, experienced service.

Your local Honeywell engineering representative will be glad to discuss your plant's instrumentation requirements with you and your consulting engineer . . . to apply the experience which Honeywell has gained through years of work in this field. Call him today . . . he is as near as your phone.

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● **REFERENCE DATA: Write for Catalog 2300, "Evenly Graduated Flow Meters"**

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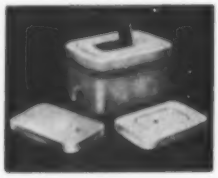
BROWN INSTRUMENTS

First in Controls

"ART" CONCRETE
provides
VALVE & METER BOXES
to suit your every requirement!



Illustrated: just a few of the many types and styles of boxes developed during our forty-two years of leadership in the field.

ONE-PIECE METER BOXES (No. 38 Series shown) . . . This style of meter box comes in a wide range of sizes to accommodate ¾" to 3" meter and shut-off. Wide collar at top provides superior strength and soil bearing. Reinforced concrete or cast iron covers available. Extension sections may be had for extra depth.

SECTIONAL METER BOXES . . . Each section of these reinforced concrete boxes securely rests in the cover seat of the tier below. Available in standard widths and lengths up to 60" i.d., and may be assembled on the job to any required depth in units of 12" and 18".

GATE VALVE BOXES . . . Extensible boxes designed for use in locations subject to heavy vehicular traffic. Cast-iron rings anchored in sturdy concrete body support heavily ribbed cast-iron covers. Boxes may be used with any metallic or non-metallic pipe as a sleeve extension.

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Dependable because they are tough and rugged. Made to withstand the wear and tear of the modern day strain and stress. For generations of incomparable service, only cast iron pipe can qualify. Serving the industry with Super de Lavaud Cast Iron Pipe, centrifugally cast, in modern long lengths.

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CHLORINE GAS CONTROL EQUIPMENT

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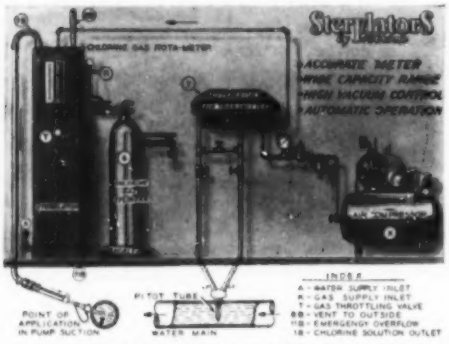

THE EVERSON AIR-O-MATIC SYSTEM
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OF GAS FEED TO LIQUID FLOW

TYPICAL INSTALLATION
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ANY ONE CAN INSTALL
EASY TO OPERATE
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The famous Rockettes of Radio City Music Hall entertain millions of people yearly with their precision-perfect dance routines.

Our experienced Technical Service Team coordinate their efforts too. They have developed a special knack of running a series of taste and odor tests in your plant without disrupting your regular routine.

After checking the use of Aqua Nuchar Activated Carbon alone and with your other chemicals from raw water to clear wells, our Threshold Odor Specialists will make a recommendation that, nine times out of ten, will give you more palatable water at less cost for over-all chemical treatment. Why not arrange to have our Threshold Odor Specialists visit your plant?

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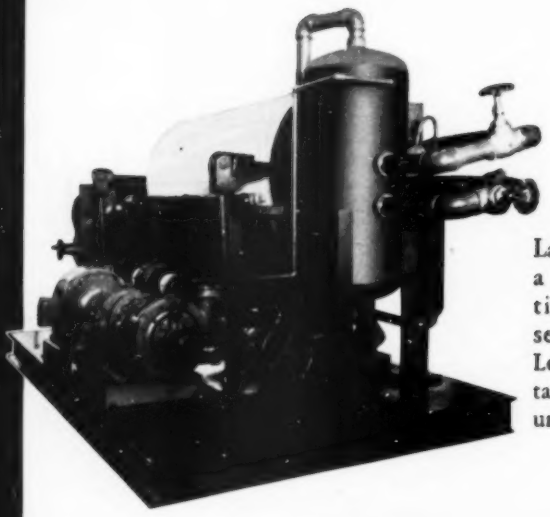
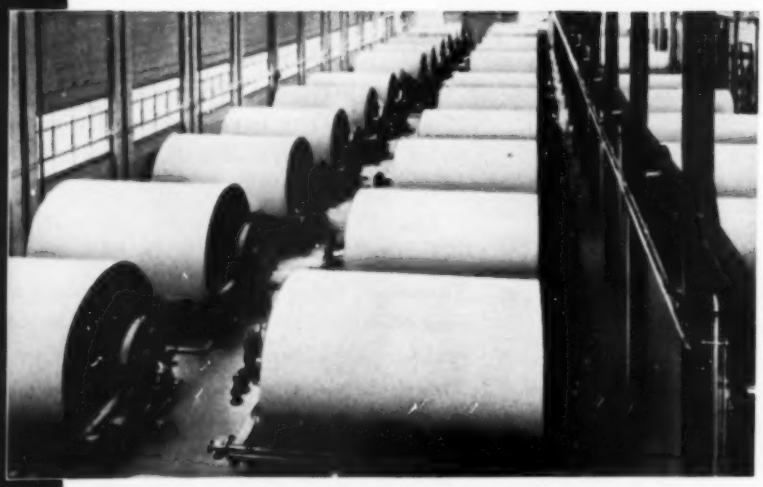


Large or small—a Conkey filtration plant can serve you well. Left, a self-contained package unit.

CONKEY FILTERS FOR SLUDGE

66 Conkey Sludge Filters installed in one plant of Chicago Sanitary District. Built to exacting specifications and rigid design requirements.



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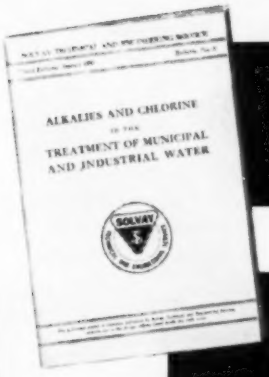
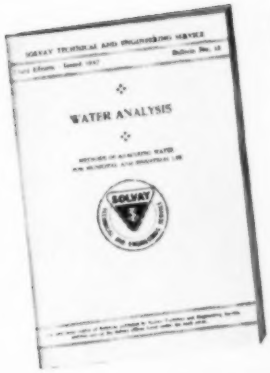
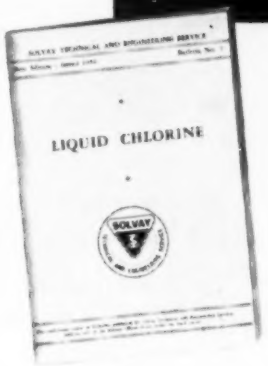


Do you have these SOLVAY TRADE-MARK REG. U.S. PAT. OFF. TECHNICAL BULLETINS?





Are you a water plant operator? . . . sewage plant operator? . . . water engineer? If your work involves the treatment of water and sewage, you should have copies of these Solvay Technical and Engineering Service Bulletins. Bulletin 5 covers properties and handling of Soda Ash; Bulletin 7 gives the properties plus handling information on Liquid Chlorine. Bulletin 8 discusses alkalies and chlorine in the treatment of municipal and industrial water, while Bulletin 11 talks about methods of analyzing water. These Bulletins are available on request; there's no cost. Use the coupon to get your copies.

Another service available to you is Solvay Technical Service. This staff is prepared to offer you assistance on your problems, without obligation. For details, see your Solvay representative.

For Water and Sewage Treatment

SOLVAY

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SODA ASH

CALCIUM CHLORIDE

Soda Ash · Caustic Soda · Chlorine · Sodium Bicarbonate Caustic Potash · Calcium Chloride · Potassium Carbonate Specialty Cleansers · Ammonium Bicarbonate · Sodium Nitrite Sesquicarbonate of Soda · Ammonium Chloride · Para-dichlorobenzene · Ortho-dichlorobenzene · Monochlorobenzene

SOLVAY PROCESS DIVISION, Allied Chemical & Dye Corporation
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Allied Chemical

Please send me copies of the Solvay Technical Bulletins I have checked below. I understand there is no cost or obligation.

- ☐ Bulletin No. 5—Soda Ash
- ☐ Bulletin No. 7—Liquid Chlorine
- ☐ Bulletin No. 8—Alkalies and Chlorine in the Treatment of Municipal and Industrial Water
- ☐ Bulletin No. 11—Water Analysis

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Company.....

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City..... Zone..... State..... BS-5

You Can't Beat Steel Pipe for Strength

Bethlehem Tar-Enameled Steel Pipe is widely used for water and sewage service because of its resilience, resistance to shock and corrosion, and leakproof joints. But the most important reason for its popularity is its great strength, which is evident in the chart below.

The chart shows the theoretical working and bursting pressures for various pipe diameters and thicknesses. The pressures shown are based upon the use of steel conforming to ASTM Specification A-283, Grade B, having a minimum ultimate tensile strength of 50,000 psi. When exceptionally severe working pressures are encountered, the use of higher strength steel is recommended for greater economy. The nearest Bethlehem office will be pleased to supply complete information.

THEORETICAL INTERNAL PRESSURES OF STEEL PIPE

	1/4 in.			5/16 in.			3/8 in.			7/16 in.			1/2 in.		
DIAM	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WORK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WORK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WORK PRESS PSI	MIN BURST PRESS PSI
22	63	365	1135	78	465	1420	93	550	1700	109	640	1985	124	730	2270
24	69	335	1040	86	420	1300	102	505	1560	119	585	1820	136	665	2080
30	86	270	835	108	340	1040	129	405	1250	150	475	1455	170	535	1670
36	106	225	695	130	280	870	155	340	1040	181	395	1210	206	445	1390
42	119	195	595	148	240	745	177	285	890	206	335	1040	234	380	1190
48	137	170	520	171	210	650	203	250	780	236	290	910	268	330	1040
54				192	190	580	230	225	695	267	260	810	303	295	925
60				214	170	525	255	200	625	296	235	730	336	265	835
72							309	170	520	359	195	605	408	220	695
84							357	145	450	412	170	520	470	190	595
96	The recommended minimum wall thickness is approximately the pipe diameter divided by 165. Pipe having this diameter-thickness ratio, when backfilled and properly tamped, will withstand any depth of cover. For buried pipe, the recommended minimum thicknesses are shown immediately above heavy black line.									470	145	455	539	165	520
108													611	150	465
120													669	135	415

$$P = \frac{t \times T_s}{r}$$

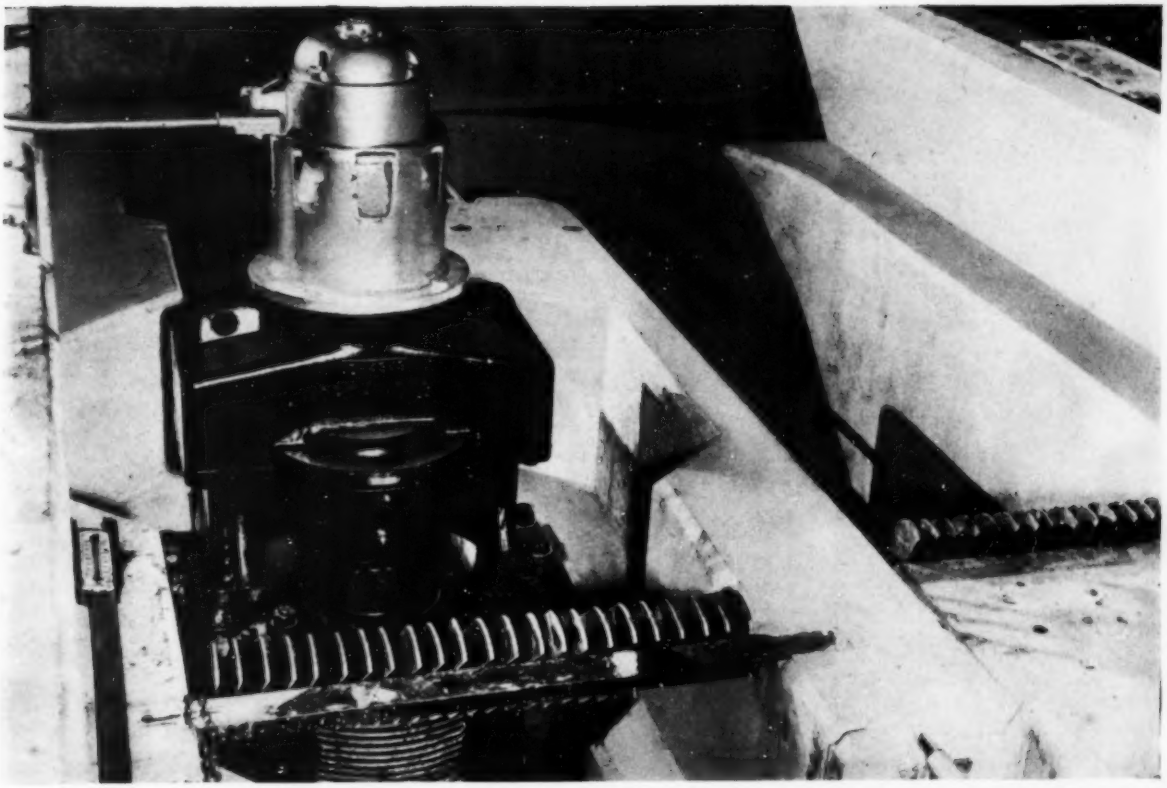
P = internal pressure, psi
t = thickness, in.
T_s = allowable unit stress = 60% x 27,000 (yield point) = 16,000 psi
r = radius of pipe, in.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM *Tar-Enameled* STEEL PIPE



WORTHINGTON COMMINUTOR IS EASILY INSTALLED TO HANDLE LARGE VARIATIONS IN FLOW like this one at the Madison-Chatham (N. J.) Sewage Treatment Plant. Maximum wet-weather flows are occasionally as high as five times the average design dry-weather flow. An overflow screen is installed on top of the comminutor to screen flows in excess of the comminutor's capacity. Screenings are later raked down into the comminutor during period of normal flow. The overflow screen makes the comminutor independent of the by-pass on right which may later be used as a channel for a second comminutor. Plant Superintendent is Edward P. Molitor.

Madison-Chatham, N. J., installation proves adaptability of Worthington COMMINUTOR

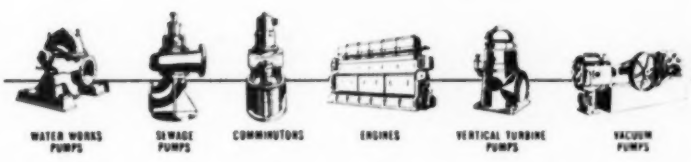
Typical example of the adaptability of the Worthington comminutor is the story of this installation at the Madison-Chatham Joint Meeting Sewage Treatment Plant in Chatham, N. J.

Engineers everywhere especially like the Worthington comminutor because:

- It can be readily installed in new or existing straight-flow rectangular channels.
- Cutter-racks are quickly removable for sharpening or replacement.
- It may be flooded without damage because it's protected by a mercury seal.

Worthington's public works specialists are ready to work with your community's engineer in solving screening problems—as well as other problems in sewage, water works, or municipal power generation. Write for Comminutor Bulletin W-2010-B3. Worthington Corporation, formerly Worthington Pump and Machinery Corporation, Public Works Division, Harrison, N. J.

W-2.5



All Major Public Works Equipment Under One Responsibility

WORTHINGTON

Public Works Equipment

Mobile Prefers Concrete Pressure Pipe

Part of the new water supply project completed last year in Mobile, Alabama, included the installation of sixteen miles of concrete pressure pipe. Nine miles of 60-inch and seven miles of 48-inch pipe were laid to carry the 45,000,000 gallons of water Mobile uses in an average day.

Mobile engineers selected concrete pressure pipe because it is economical to install and maintain . . . it will carry water for generations without reduction in carrying capacity due to tuberculation or corrosion . . . and it is immune to rupture or blow-out.

Concrete pressure pipe offers these same advantages for the water systems of any size community. It is available in a wide range of diameters and can be installed to fit individual requirements. Let us show you how concrete pressure pipe can bring your community "water for generations to come."

Water for Generations to come

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

SPECIFY RODNEY HUNT

FOR SLUICE GATES

Standard Sizes: 6" to 108" diameter
Larger Rectangular Sizes
for Special Installations

Versatility plus! With new equipment and enlarged facilities, we can meet your specification and delivery requirements for cast iron bronze-mounted sluice gates. Specify exactly the right gate from twelve standard types . . . over 2000 combinations of types and sizes! Rodney Hunt sluice gates are the product of skilled foundry practice, precision finishing, and carefully engineered construction: they resist deflection and assure dependable, low-maintenance operation.

Free! 232-page color catalog

This is one of the most complete works in the field. It contains photographs, drawings, specifications and complete descriptions of our sluice gates, timber gates, hoists, valves, racks and rakes, plus a valuable 28-page section of engineering data on hydraulic problems.

This important catalog was especially prepared and edited for consulting engineers, contractors and other executives who are *actively* engaged in the water control field. Please write on your letterhead for Catalog WCA-952. Rodney Hunt Machine Co., 84 Lake St., Orange, Mass., U.S.A.

RODNEY HUNT

Water Control Apparatus Division

Manufacturing Engineers Since 1840

DRESSER JOINTS, FITTINGS, REPAIR CLAMPS, SLEEVES

A complete line for all types and sizes of water pipe

FOR LEAKY BELL & SPIGOT JOINTS
Style 60
ADJUSTABLE BELL-JOINT CLAMP

Highly adjustable Style 60 has wide use in water repair work. Especially good on locations subject to vibration, such as under railroad tracks, heavy traffic spots, and on bridges. Sizes 3" through 60" CIP.

FOR BRANCH CONNECTIONS TO EXISTING LINES
Style 91
PIPE SADDLE

A quick easy way to make branch connections to existing lines when tapping sleeves, tees, or other methods are not desirable. Standard saddle is equipped with exclusive Dresser rubber gasket. Also available with lead gaskets or without gaskets. Malleable and steel construction for steel and CIP. Sizes 1½" to 20" OD.

FOR SUPPLY AND DISTRIBUTION LINES
Style 38
DRESSER COUPLINGS

Proved dependable for over sixty years, on thousands of miles of municipal supply and distribution mains. Special rubber gaskets make a permanent joint, flexible enough to permit laying curves with straight pipe. Wrench is only tool needed. Available for plain-end steel, cast iron or other pipe, ⅜" ID to 72" OD and larger.

FOR JOINING SMALL PIPE
Style 65
"NO-THREAD" FITTINGS

No threading or exact pipe alignment is necessary with these simple, speedy fittings. Just stab over plain pipe ends and tighten bolts with a wrench.

Style 90 (steel) for underground work, and Style 88 (brass) for copper tubing available. All standard shapes.

FOR SPLITS AND BREAKS IN CAST IRON PIPE
Style 82
REPAIR & TAP SLEEVE

Handy sleeve repairs breaks, holes and splits in straight run of CIP quickly and securely, without service interruption. Highly adjustable for off-size pipe. Also makes a handy tapping sleeve, when needed. Sizes 4", 6", 8" CIP.

FOR LEAKS, BREAKS, SPLITS UP TO 8" IN CIP
Style 57C
CAST SPLIT SLEEVE

Standard equipment with emergency crews for repairing unexpected breaks requiring immediate attention. Used successfully for years by water departments everywhere.

Each sleeve is tested with 60-lb. air pressure and 500-lb. hydrostatic pressure before shipment. Sizes 2" to 12" CIP.

Each Dresser Style is designed to meet a specific problem of pipe joining or repair. Convenient to use anywhere, Dresser Couplings are standard equipment with municipal water departments who appreciate the simplicity and speed of these couplings under difficult working conditions. Shown above is a representative group of Dresser products for the municipal field. A complete list includes: Couplings · Insulating Couplings · Reducing Couplings · Long Sleeves · Tees, Ells, Crosses · Pipe Saddles · Expansion Joints · Split Repair Sleeves · Bell-Joint Clamps · Collar, Screwed Fittings, Clamps, Band and Saddle Clamps · Service Fittings.

Catalogs and further information on request

DRESSER
ONE OF THE DRESSER INDUSTRIES

MANUFACTURING DIVISION

Dresser Manufacturing Division (One of the Dresser Industries), Bradford, Pa. Sales Offices: New York, Philadelphia, Chicago, Houston, San Francisco. Warehouses in Houston and South San Francisco. In Canada: 629 Adelaide St., W., Toronto, Ont.

These Two Methods End Sludge Disposal Problems

Effective as modern processes of sewage *treatment* are, they can lose much of their value if proper sludge disposal methods are not adopted.

The C-E Raymond System of Flash Drying and Incineration offers two completely modern methods of sewage sludge disposal – both performed by compact, reliable equipment.

Flash Drying by the C-E Raymond System is a continuous process in which vacuum filtered sludge – if uncontaminated with undesirable industrial wastes – is efficiently heat dried to a marketable fertilizer or soil conditioner retaining all its original nitrogen, but eliminating the objectionable qualities of the original wet sludge. In a well designed and operated "activated plant" the revenue from the sale of fertilizer is sufficient to cover the operating costs of both the drying and vacuum filtration.

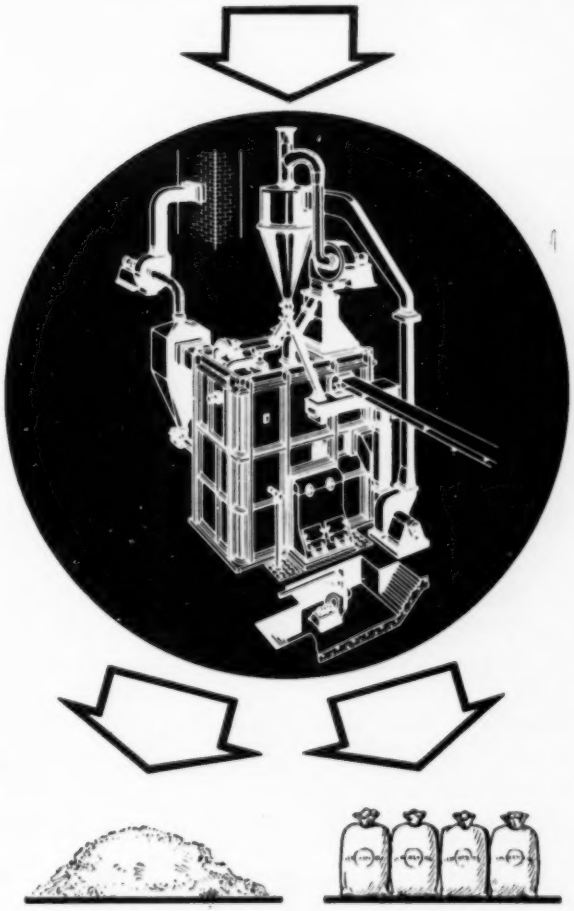
Incineration by the C-E Raymond System is an alternate, optional method. Where the production of fertilizer is not desired or the sludge is unsuitable, it is flash dried and then completely burned *in suspension* to an easily disposable, sterile ash.

The two methods can be combined in one system and used alternately as current market situations dictate. The entire design is completely flexible and can easily be tailored to suit the requirements of any community, large or small.

The services of C-E specialists are available to help you plan for the end of atmospheric or stream pollution in your community, as it has been done in so many others. For specific recommendations on the most practical answer to your sludge disposal problems, get in touch with one of the Combustion offices listed at the right.

SLUDGE

As a vacuum filter cake or thickened sludge from any type of sewage treatment process.



ASH **and/or** **FERTILIZER**

As a fine dust, free from clinker and unburned organic materials.

As a dry powder, containing all the original fertilizer ingredients.

Industrial Sludges, Too *are effectively and economically disposed of in C-E Raymond Flash Drying and Incineration Equipment. Write for details.*

B634

COMBUSTION ENGINEERING, INC.

FLASH DRYER DIVISION

1315 North Branch Street
Chicago 22, Illinois

Western Office: 510 W. Sixth, Los Angeles 14, Calif.
Eastern Office: 200 Madison Ave., N. Y. 16, N. Y.

WHAT DO WE MEAN BY MODERNIZED CAST IRON PIPE?

We mean still *stronger, tougher pipe with sustained carrying capacity* because it is centrifugally cast and centrifugally cement-lined.

All of our member companies have centrifugal casting facilities for producing tougher, stronger *modernized* cast iron pipe. All can supply this pipe with cement lining, centrifugally applied.

This centrifugally-cast pipe is lined, when conditions require, with cement mortar centrifugally applied. Result—a tuberculation-proof pipe with sustained carrying capacity and, therefore, reduced friction loss and pumping costs.

If you want the most efficient and economical pipe ever made for water distribution, your new mains will be laid with centrifugally-cast and centrifugally-lined cast iron pipe with either bell-and-spigot or mechanical joints. Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3.

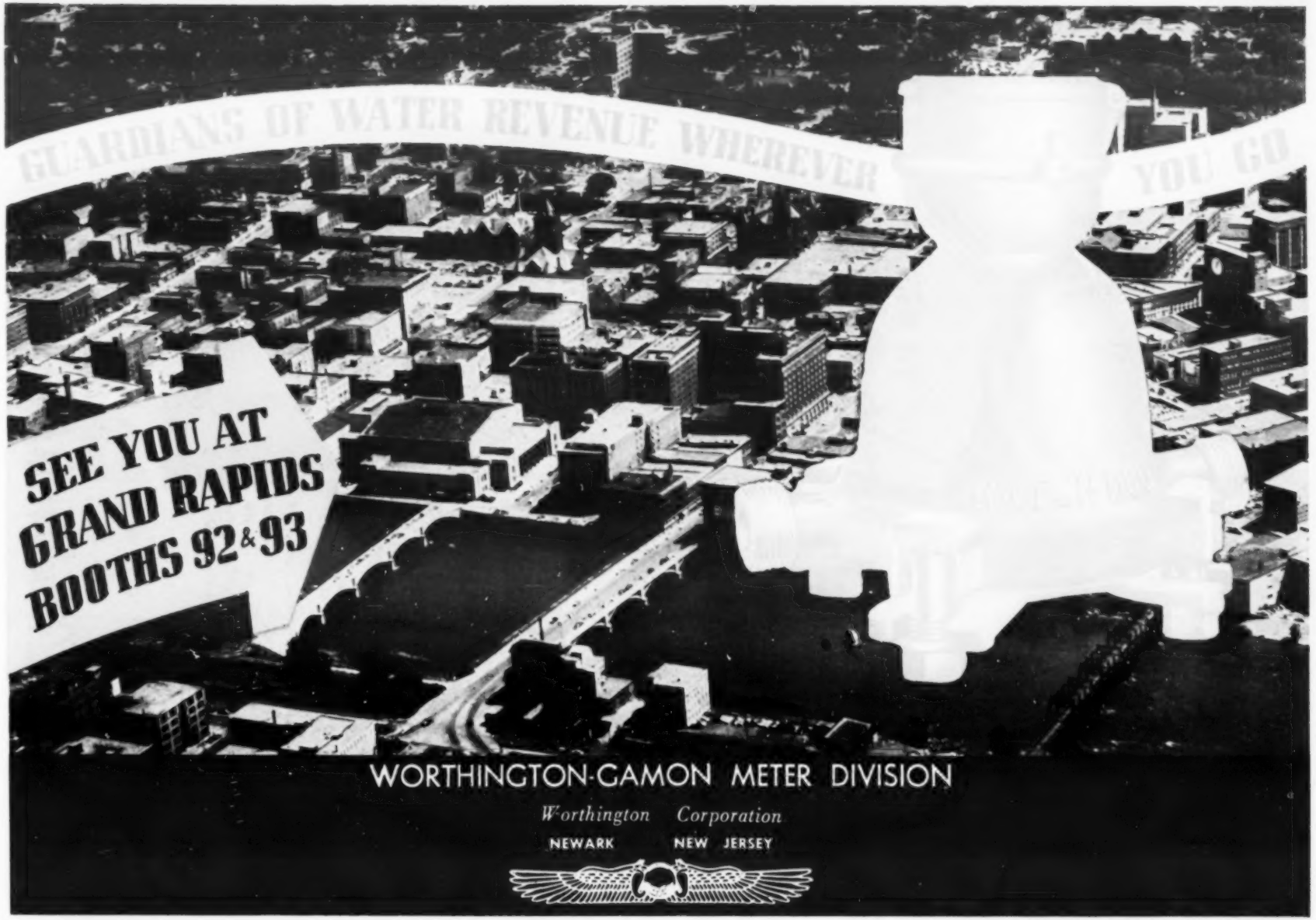
CAST IRON

The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

Modernized **cast iron**

This cast iron water main, uncovered for inspection, is in its 104th year of service in Buffalo, N. Y.—one of more than 40 cities with century-old water or gas mains in service.

pipe *for Modern Waterworks Operation*


GUARDIANS OF WATER REVENUE WHEREVER
YOU GO
SEE YOU AT
GRAND RAPIDS
BOOTHS 92 & 93
WORTHINGTON-GAMON METER DIVISION
Worthington Corporation
NEWARK NEW JERSEY

this "whirling tube" doesn't clog!

This "whirling tube" is inside the amazing Fairbanks-Morse *Bladeless* Impeller Pump . . . just a "whoosh" and fibrous material goes right through.

Fairbanks-Morse engineers designed this impeller without blades or projections that catch and hold trash—it's truly non-clog. Even a man's complete coveralls went through a 4-inch pump without clogging!

See your Fairbanks-Morse Distributor or Local Branch Office about this *Bladeless Impeller* Pump . . . or write Fairbanks, Morse & Co., Chicago 5, Illinois.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS

NEWPORT NEWS MECHANICAL RACK RAKE

WATER users troubled with trash are invited to write for new descriptive rack rake catalog.

THE Newport News Mechanical Rack Rake is a power-operated rake for cleaning trash racks at water intakes for hydroelectric plants, steam plants, pumping stations, canals and similar installations. It cleans the rack bars of trash and reduces a former major hand operation to one of minor periodic activity. With Newport News Mechanical Rack Rake installations, one man per shift can, under ordinary conditions, keep the racks clean for a dozen bays.

NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

NEWPORT NEWS, VIRGINIA

ROOTS CAN'T PENETRATE TYLOX JOINTED SEWERAGE AND DRAINAGE LINES

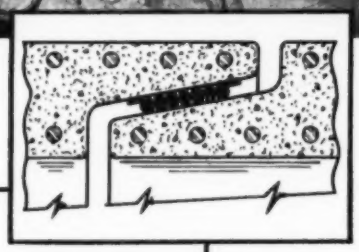
Engineers and contractors are assured of *permanently* rootproof joints when their tongue-and-groove, or bell-and-spigot pipe installations are protected with Tylox *Flexible* Rubber Gaskets.

Tylox seals by compression, not adhesion—as in the case of bituminous or mortar jointing materials. When the pipe is shoved home, Tylox "packs" the joint's annular space tight by mechanical action, and the natural resilience of the rubber *keeps* it tight . . . Tylox won't shrink or crumble, to leave spaces in the joint for the entrance of ground water or roots.

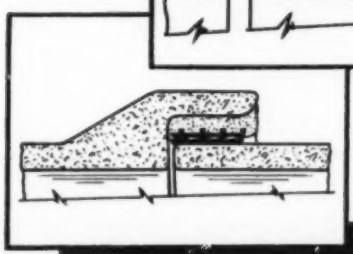
Tylox *flexibility* which assures rootproof and leakproof joints, also permits pipe laying in wet trenches, and immediate backfilling . . . Tylox compensates for angularities in the line, and the presence of mud or water during jointing has no effect on its seal.

Tylox is made of a specially compounded rubber that *stays* flexible and is resistant to sewage and industrial waste acids and alkalies. It won't corrode or deteriorate. Underground, and under compression, Tylox Joints outlast the pipe itself.

Call for Tylox jointing gaskets on your next pipe project. Assure faster pipe laying, and *know* your line is permanently protected against leakage or root penetration.



TYPE "A" GASKET under full compression



TYPE "B" GASKET under full compression

MAKING JOINTS WITH TYLOX RUBBER GASKETS IS AS SIMPLE AS A B C

Cement tongue and snap on TYLOX gasket.

Lubricate sliding surfaces with TYLOX cement.

Shove the pipe home to line and grade.

HAMILTON-KENT MANUFACTURING COMPANY
KENT, OHIO

1787

Pipe Repair Jobs...

PLUMBER	$2.84 PER HOUR
MASON	$3.13 PER HOUR
CARPENTER	$2.63 PER HOUR
PLASTERER	$3.08 PER HOUR
PAINTER	$2.57 PER HOUR

add up to just one thing...

CORROSION COSTS YOU MORE THAN WROUGHT IRON

There's nothing like a repair job to point up the false economy of installing low-first-cost piping. The original installation is quickly made by a pipe fitter, but the replacement calls for hours of work by as many as five crafts, all carrying a high price tag. This first failure may wipe out initial savings, a dozen times over. And loss in production or utilization during shutdown may amount to far more than the maintenance charge.

It all adds up to one thing—*corrosion costs you more than wrought iron.*

In literally thousands of applications where corrosion is a threat to service life, the use of Byers Wrought Iron pipe is the soundest kind of economy move. This material's greater durability, proved in past service records, is curbing high maintenance and repair costs in a wide variety of industries.

The next time you approve or specify pipe, investigate the superior performance of Byers Wrought Iron pipe. Remember, it takes only ONE to *install* pipe, but FIVE to *repair* it!

You'll find a lot of helpful information on the control of excessive maintenance in our bulletin, WROUGHT IRON FOR PIPING SYSTEMS. Write for your copy.

Labor costs shown above are estimated national averages according to Bureau of National Affairs, Inc.

A. M. Byers Company, Pittsburgh, Pa. Established 1864. Boston, New York, Philadelphia, Washington, Atlanta, Chicago, St. Louis, Houston, San Francisco. Export Division: New York, N.Y.

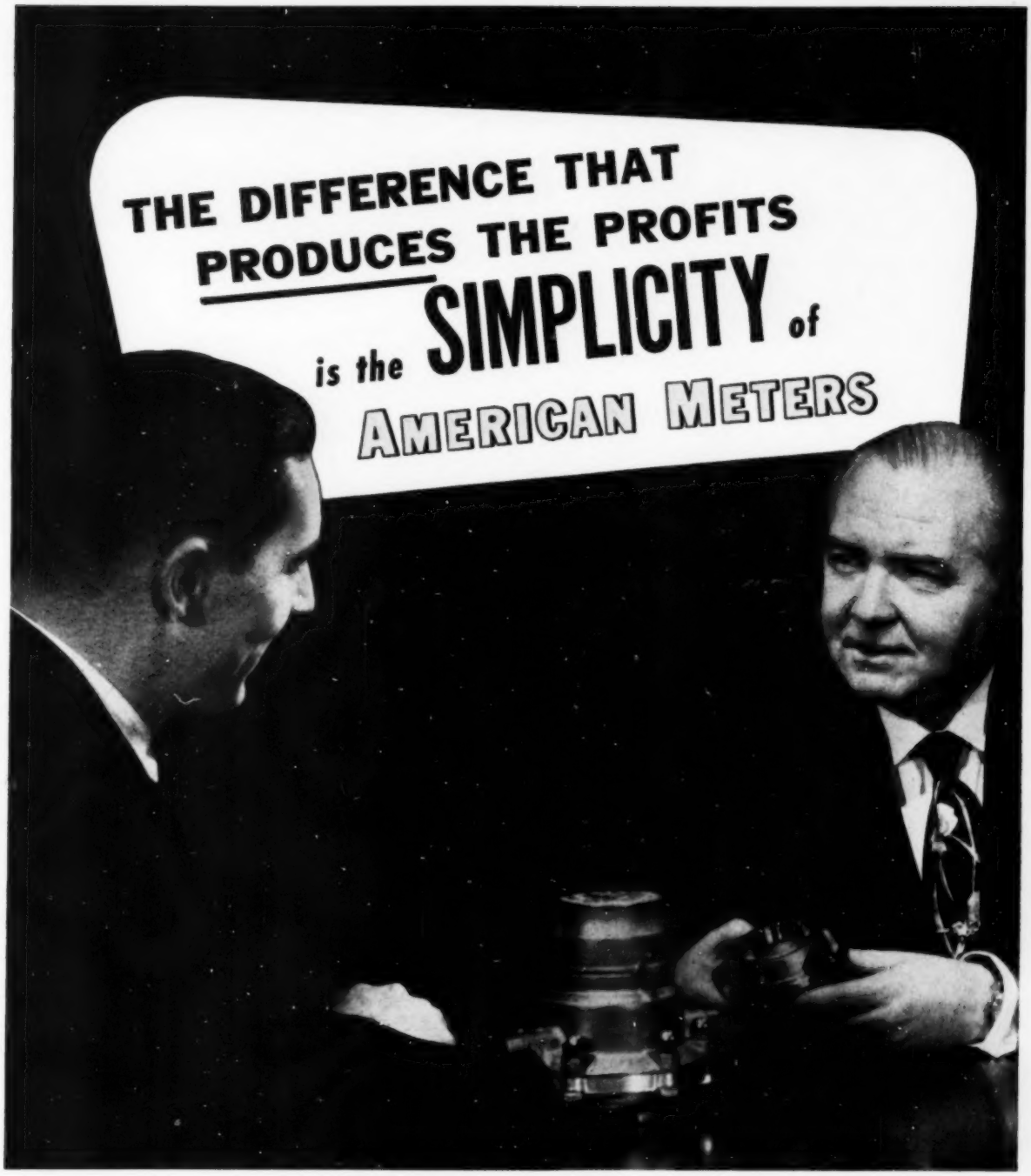
BYERS

CORROSION COSTS YOU MORE THAN WROUGHT IRON

WROUGHT IRON

TUBULAR AND HOT ROLLED PRODUCTS

ELECTRIC FURNACE QUALITY ALLOY AND STAINLESS STEEL PRODUCTS



● Most makes of Water Meters look similar, are made of the same materials, are priced competitively and are claimed to provide the same accuracy. What, then, are the differences? What values are outstanding?

American Meters stand out as the most exceptional value because of simplicity of design—fewer parts, simpler castings. This simplicity provides long life, quick easy repair. Only a small stock of interchangeable parts are needed to keep these meters producing. These benefits mean low cost efficient operation of the water department.

Ask for complete data.

BUFFALO METER CO.

2909 MAIN STREET, BUFFALO 14, NEW YORK

YOU can stop costly sewage corrosion before it starts, increase the working life of your sewage treating tanks and equipment, and cut maintenance costs to a minimum when you protect with Pitt Chem Tar Base Coatings.

These tough, durable coatings were specifically formulated to protect structures and equipment against mineral acids, alkalis, corrosive vapors and atmospheric conditions. Leading sewage plant engineers acclaim them as the most satisfactory of all types of coatings for combating sewage corrosion.

Pitt Chem Tar Base Coatings are easy to apply and provide a protective coating up to 10 times as thick as ordinary paints. Their black color doesn't fade or discolor—even after years of use. *No other material does such a complete job of protection at so little cost.* ● Write today for recommendations on your specific problems.

W&D-4462

Write For FREE Corrosion Control Booklet

Tells where tar base coatings can save you money in your plant . . . what grades to use . . . how to apply them.

PROTECTIVE COATINGS DIVISION

PITTSBURGH
COKE & CHEMICAL CO.

Grant Building • Pittsburgh 19, Pa.

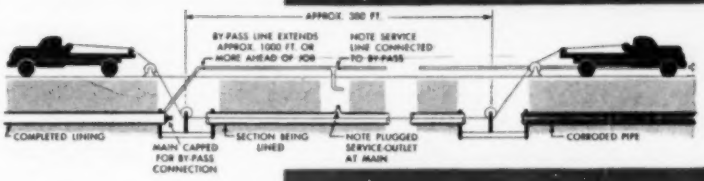
COAL CHEMICALS • AGRICULTURAL CHEMICALS • FINE CHEMICALS • PROTECTIVE COATINGS • PLASTICIZERS • ACTIVATED CARBON • COKE • CEMENT • PIG IRON

have you seen an Eskimo pipe?

Practically the only materials available to the early Eskimo for his pipe were bone, ivory and small twigs. The most primitive type of pipe was made by splitting a straight willow wand, removing the pith and hollowing out one end for the bowl, then binding the two hollowed out pieces to form the long stem. Mighty tough smoking for the Eskimo who couldn't enjoy the straight, clean and easy-drawing pipes made today!

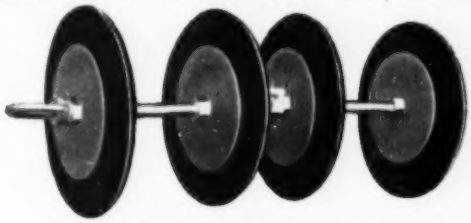
have you seen a modern pipe lining operation?

The Tate Process, applicable to water, oil and gas pipe lines, renews old iron and steel pipe "in place" as shown here in the schematic drawing. The Tate Process is applicable to pipe lines from 4" to 16" in diameter. Only momentary interruption to service is necessary while by-pass sections are installed.


APPROX. 300 FT.
BY-PASS LINE EXTENDS APPROX. 1000 FT. OR MORE AHEAD OF JOB
NOTE SERVICE LINE CONNECTED TO BY-PASS
COMPLETED LINING
MAIN CAPPED FOR BY-PASS CONNECTION
SECTION BEING LINED
NOTE PLUGGED SERVICE-OUTLET AT MAIN
CORRODED PIPE

have you seen the *Steel Scraper?* . . . It is pulled through pipe, dislodges all incrustation, corrosion and tubercles, makes inside clean and smooth.

have you seen the *Rubber Swabber?* . . . It follows the scraper and pulls out loosened material leaving pipe clear and free of debris.



have you seen the *Tate Process liner?*...It completes the renewing process by squeezing cement mortar onto the inside of the pipe wall, making the surface smooth and water-proof. Liquids move swiftly without drag.

If your worn-out pipe looks like this!

The Tate Process restores it like this!

YOU GET THESE ADVANTAGES FROM CEMENT MORTAR LINING!

- ✓ New pipe performance
- ✓ Prevents leakage
- ✓ Restores full flow coefficients
- ✓ Reduces pumping and maintenance costs
- ✓ Protects against corrosion, contamination and discoloration at much less than the cost of installing new pipe!

Pipe Linings, Inc. offers "in place" Tate Process lining service for pipe 4" to 16" in diameter and "in place" Centrifuse Process lining service for pipe 16" to 144". Complete mobile equipment and expert crews are available to bring new efficiency to your old pipe. A Pipe Linings, Inc. hydraulic engineer will be glad to discuss your problem. No obligation! Send the coupon today!

PIPE LININGS, Inc.

4675 Firestone Blvd., South Gate, California

PIPE LININGS, Inc., 4675 Firestone Blvd., South Gate, Calif.

( ) Please send complete information on how to obtain new pipe line performance from my old pipe.

( ) Please have one of your hydraulic engineers call on me.

Name_____

Title_____

Company_____

Address_____

City_____ State_____

BECKMAN INSTRUMENTS
SAVE TIME AND MONEY!

Automatic pH Equipment Eliminates Grab Sampling In Water Treatment Lab

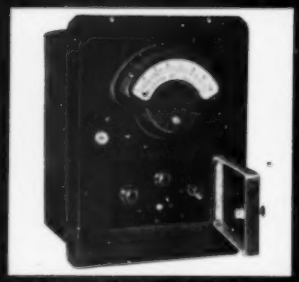
Beckman Automatic Equipment eliminates the need for almost continual grab-sampling of water for pH measurements; makes available immediate pH readings at the four vital points in the treating process; saves substantial amounts of treating chemicals by making possible closer pH control at Long Beach Water Treatment Plant, Long Beach, California.

Waste Disposal Problem Solved With Beckman Automatic pH Control

To meet an arbitrary acidity limit of pH 6.0 for industrial sewage established by county waste disposal officials—Auto-Lite Battery Corp., Paramount, California utilizes spent caustic and Beckman Automatic pH Indicator with standard recorder-controller to provide maximum sensitivity, capacity and flexibility in treatment of acid sewage without undue waste of spent caustic.

HOW YOU CAN USE BECKMAN pH CONTROL!

The application story mentioned above is only one of many ways industry is using Beckman pH Control to cut costs, boost plant efficiency and minimize waste. Have you investigated the many ways modern pH control can make important savings in your operations? Our experienced engineers will gladly study your processes—without obligation—and make helpful recommendations to fit your particular requirements.



Beckman Model R pH Indicator

For full details on the above application see your Beckman Dealer, or write for Data File 87-20.

The Beckman Model R pH Indicator illustrated above provides, in conjunction with standard recorder-controllers, automatic continuous pH measurement and control in a wide range of industrial processes. It may be wall or panel mounted and the electrodes may be installed directly in pipe lines, vats, or other grounded solutions—*eliminating need for grab-sampling.*

Operating from standard 115 v. 50/60 cycle current, the instrument can be set to maintain optimum pH at all times, insuring more uniform control and eliminating "overdosing" and waste of chemicals. Complete data on this and other Beckman pH instruments is included in Data File mentioned above. Write for your copy!

BECKMAN INSTRUMENTS
control modern industries

BECKMAN INSTRUMENTS, INC.
SOUTH PASADENA 1, CALIFORNIA
Factory Service Branches: New York—Chicago—Los Angeles

Beckman Instruments include: pH Meters and Electrodes — Spectrophotometers — Radioactivity Meters — Special Instruments

Ring the Bell!

HYDRO-TITE and FIBREX

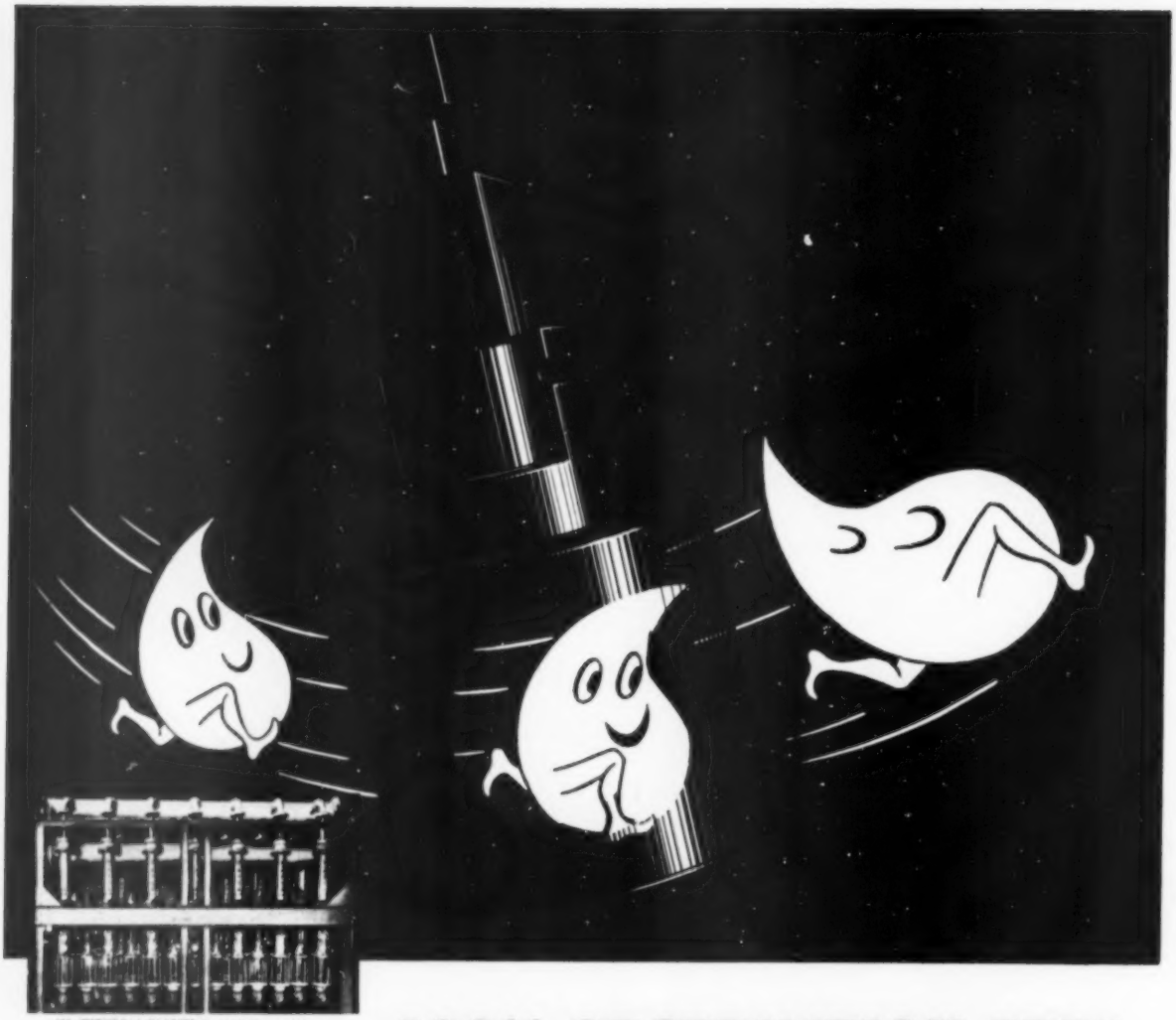
THE DEPENDABLE JOINT COMPOUND — THE BACTERIA-FREE PACKING

ring the bell every time with a perfect joint—

HYDRO-TITE

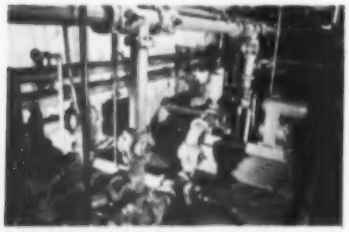
HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office 30 Church Street, New York — *General Offices and Works* W. Medford Station, Boston, Mass.



IN CHEMICAL PLANTS A.C.F. Round Port Valves provide quick emptying, full protection against corrosive action.

IN THE PETROLEUM AND GAS INDUSTRY A.C.F. Round Port Plug Valves provide full-area flow with fast shut-off.



IN SEWAGE PLANTS A.C.F. Valves offer uninterrupted flow. CYLINDRICAL plug actually shears obstructions.

100% OBSTRUCTION FREE

The passage of an A.C.F. Round Port Lubricated Plug Valve exactly conforms to the size and shape of the pipe. Ideal for capacity flow of abrasives and suspensions, these valves have the same quick, quarter-turn shut-off feature of rectangular port A.C.F. CYLINDRICAL "Full Pipe Area" Plug Valves. In addition, an A.C.F. Valve cannot wedge in its seat. Why tolerate a less efficient valve?

A.C.F. CYLINDRICAL FULL PIPE AREA PLUG VALVES

Write for Catalogue 4-WS, American Car and Foundry Co., Valve Division, 1501 E. Ferry Ave., Detroit 11, Mich.

Representatives in 50 Principal Cities

Dependability

Operators of Roberts-equipped water treatment plants look forward to the same trouble-free service tomorrow that they have come to count on since their equipment was installed.

Even in little things, Roberts follows through the years . . . an accidentally broken operating table handle is supplied to match the originals . . . replacement valve parts are shipped from stock or precisely made to the original pattern. Modernization of design has never obsoleted any Roberts equipment.

There has not been, or will there be, an "orphan" with the name Roberts attached. Integrity is built into every piece of Roberts equipment . . . for the years.

Roberts Filter . . . Nameplate of dependability

ROBERTS FILTER

Manufacturing Co.
Darby, Penna.

TENNESSEE CORPORATION

Ferri-Floc

FERRIC SULPHATE

COAGULATION... AT IT'S BEST...

That has been the experience of so many of the country's larger water treatment plants, such as the one above. Here is how plant managers in various parts of the country feel about Ferri-Floc:

"Laboratory tests were run on Ferric-Sulphate and Aluminum Sulphate and the results recorded. Results from these laboratory tests were that coagulation with Ferri-Floc was equal or superior in all cases to Aluminum Sulphate. We are now using Ferri-Floc."

"We were having trouble with Copperas caking in bulk storage hoppers. We decided to investigate the use of Ferric-Sulphate. Experiments were conducted which proved conclusively that Ferric-Sulphate could be stored in bulk over long periods of time without caking. Excellent coagulation was obtained at all times. We have been using Ferri-Floc since these experiments were run in 1942."

"Ferric-Sulphate has been used in our plant continuously for the past ten years and results have shown for the type of water we have to treat that Ferri-Floc is the most effective coagulant we can use."

Free Literature!

We would be pleased to supply you without charge a 38-page booklet that deals specifically with all phases of coagulation. Send postal card or letter to—

TENNESSEE CORPORATION

TENNESSEE CORPORATION

617-29 Grant Building, Atlanta, Georgia

NEW CHAPTERS IN AN OLD STORY*

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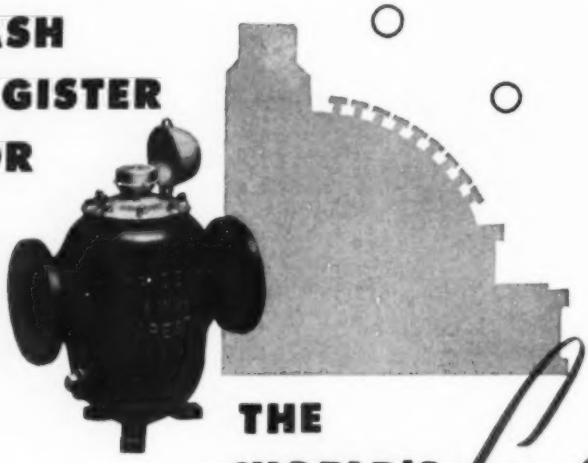

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CHARLES H. CAPEN

Increasing Awareness of the Necessity for Cooperation

A Guest Editorial
by the President of
The American Water Works Association

WHILE for some years water works and the sewage works associations have held many meetings under joint sponsorship, there has been a reasonable amount of good-natured bantering between the respective groups. There are many whose activities enter both fields and they are frequently amused, as well as sometimes annoyed, at the apparent rivalry. Realization that a mutual interest exists appears to have been gradually breaking down the barriers and simultaneously there is an increasing awareness of the necessity for cooperation between those considering themselves as strictly water supply men and those engaged in sewage or industrial waste disposal.

Speaking at the meeting of the New Jersey Sewage and Industrial Wastes Association on March 13, 1953, in Atlantic City, N.J., Dr. C. K. Banks, vice-president of The Metal & Thermit Co. of New Brunswick, N.J., struck a new note which should be harmonized with the others. This note was to the effect that Industrial Management comprised an additional group which should cooperate with pollution abatement associations. He further pointed out some of the associated water supply problems of industry.

The sort of symposium in this vein, which was one of the keynotes of the N.J. Sewage and Industrial Waste Assn. meeting, has been tried in various forms with different degrees of success. There is little doubt, however, but that its continuation is greatly to be desired.

As time goes on, citizens are becoming increasingly critical of the water that they drink, the source from which it comes, and, to a greater extent, the technical features of its treatment. Likewise, they demand higher standards for recreational waters in which they bathe, as well as those from which their fish or seafood is obtained. Under such conditions, it is only natural that those who have the responsibility of looking after the quality of water are not only painfully aware of this situation, but also realize that such circumstances create a prime necessity for cooperation between agencies engaged in water supply, those dealing with sewage treatment and those representing industry in pollution correction or improved quality of water supply for industry.

Anyone who has had experiences with phenol tastes in water can well appreciate the need for constant vigilance in respect to this item alone. To illustrate how sensitive this is, it may be pointed out that one instance exists where a very strong wind blowing dust from a newly surfaced highway, deposited tar laden material on the surface of a reservoir, and phenolic tastes resulted. In another case where men were engaged in placing a new roof coating on a

building and immediately afterward were engaged in cleaning screens at an intake, phenolic tastes were again noted.

Perhaps the keynote for some of the recent attitudes regarding the part to be played by industry was cited by L. L. Hedgepeth who said, in a paper presented before a meeting of the Am. Society of Civil Engineers in New Orleans last year, and which was printed in the September 1952 issue of this magazine, that a new slogan might well be adopted to the effect that "*Realism* is the spirit of current industrial thinking on stream pollution." This, of course, reflects an advance in thinking that applies to all phases of stream usage.

Figures advanced by Schwab of the U.S. Public Health Service at the A.P.W.A. meeting in Los Angeles last fall showed clearly that while the large bulk of people living in population centers are served by sewers, about 38 per cent discharge raw sewage, and more than half of those served by treatment plants have inadequate treatment.

Under the conditions enumerated above, with the rapid growth in use of synthetic detergents as a constant threat to both water and sewage treatment processes, and with industry requiring increasingly higher percentages of the water available in streams, from the ground, or other bodies of water, there is certain evidence that only by joint efforts can a reasonable solution be attained.

The situation in the industrial areas of Germany prior to World War II constitutes an outstanding example of one method by which problems of this type can be met, at least under similar conditions. Some rivers in this country have reached a similar point of near saturation with respect to the assimilation of sewage and industrial wastes without nuisance production. The main distinction between the two is that we have not yet become accustomed to the necessity for adequate policing, as has been practiced abroad. Because of our dislike for such enforced rulings, it is doubly necessary that we try to achieve the goal by other means—namely, cooperation of the most genuine sort.

A few trips around streams in populated centers, and even many in more or less isolated areas, will reveal pollution so obvious that no analyses are necessary to convince even a novice that there is much to be done. For many years sanitarians have been well aware of this. The difficulty has been that each group has been left to work out its own individual problems. Examples exist where necessity has forced the various interests to attempt to solve their mutual problems jointly. An outstanding instance is that of the Passaic River valley in New Jersey, where the statutes give a wide range of police powers, but where most results have been achieved by direct agreement and cooperation between an important water utility and industry rather than by law suits or through force available in the State Dept. of Health.

Ultimately this type of assumption of responsibility on the part of agencies of water supply and sewage treatment, together with industry, will be the crux of successful use of our tremendous heritage —WATER, the one universal raw product of industry and that element so essential to the convenience and comfort of modern living.

Charles H. Capen

Chief Engineer, North Jersey District Water Supply Comm., Wanaque, N.J.

WATER & SEWAGE WORKS

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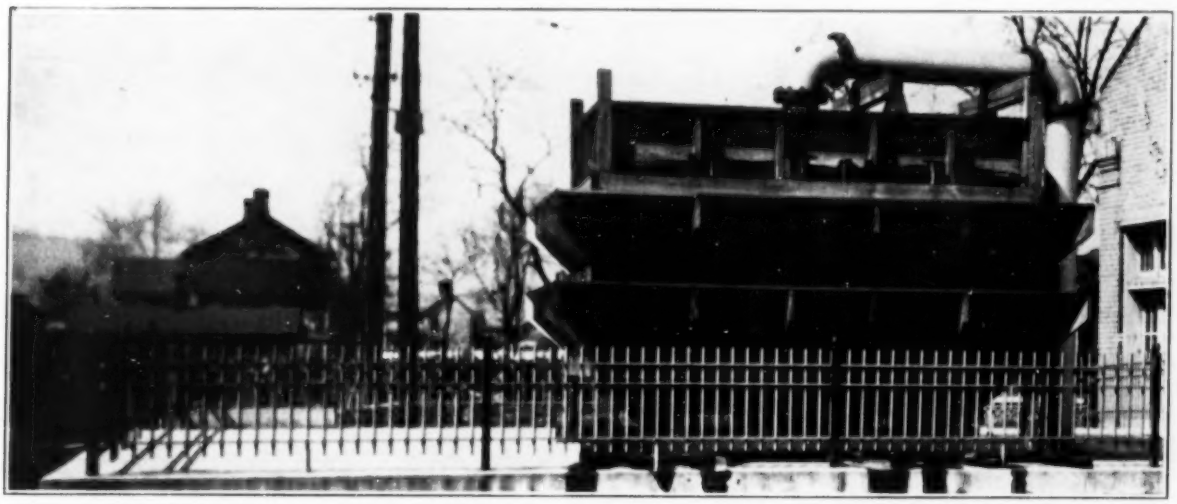

Fig. 1—COKE TRAY aerator preceding manganese zeolite filters and zeolite softeners, Coraopolis, Pa.

Iron and Manganese Removal

by ESKEL NORDELL, *Administrator of Laboratories, The Permutit Co, New York, N.Y.*

IRON and manganese can be considered two of the most troublesome elements to be found in natural water supplies. As to the troubles caused by these elements, they are legion. To mention just a few: in the household—porcelain fixtures, glassware, laundered materials, etc., develop unsightly stains which are very difficult to remove, and tea and coffee made with such waters become muddy-looking, unpalatable beverages. In the industries, even more serious difficulties are encountered—cotton, wool, and other textiles cannot be processed in such waters; rayon manufacture is impossible; dyeing is uneven and spotty; tanning is difficult; beverages develop troublesome and unsightly precipitates; quality pulp and paper production is impossible; etc.

In addition to these various difficulties, iron and manganese tend to favor the growth of iron and manganese micro-organisms popularly lumped together under the designation "crenothrix." These iron and manganese crenothrix growths clog pipe lines, meters, fixtures, nozzles, recirculating systems, and other water-handling equipment, cutting down flow rates and frequently breaking loose in large, clogging masses which, as they decompose, impart objectionable tastes and odors to the water.

The commonest form in which these metals occur is in the reduced state, as ferrous bicarbonate or manganous bicarbonate. These divalent bicarbonates are colorless compounds which exist only in solution and are most commonly found in deep well waters or spring waters. They can also occur, in cases of iron or manganese pickup, when an unaerated water is pumped through distribution systems containing the insoluble, higher oxides or hydrated oxides. Under such conditions, a portion of these deposits may be reduced to the divalent form which then goes into solution.

The second commonest form in which iron and manganese occur is in an organic or colloidal form, usually in surface waters and lower strata water in deep reservoirs, sometimes in shallow well waters and occasionally in deep well waters. Almost invariably, these waters have a rather high color, due to the organic matter present.

A third form is as the divalent sulfates—ferrous sulfate or man-

Ed. Note: The author is also author of the highly useful text "Water Treatment for Industrial and Other Uses" from which the accompanying tables have been reprinted.

Fig. 2—WOOD SLAT TRAY aerator for iron removal on roof preceding filtration, and zeolite softeners, Genoa, Ohio.

ganous sulfate, but these are found only in acid waters such as (1) acid mine waters, (2) acid well or spring waters in the neighborhood of mines or contaminated by trade wastes or (3) acid surface waters which similarly have been contaminated by acid mine waters or trade wastes.

A fourth form, of secondary origin and which applies almost entirely to iron, is as the suspended, insoluble higher oxide formed by corrosion of the distribution system or by aeration of a water containing ferrous bicarbonate, either of which causes the familiar "Red Water." In the absence of oxygen and presence of sulphides foul smelling "Black Water" issues from fire hydrants or dead end blow-offs.

Ferrous Bicarbonate—Manganous Bicarbonate

Iron or manganese, when present as the divalent carbonates, may be removed by one of four processes:

(1) Aeration, followed by settling, and filtration
(2) Oxidation with Chlorine, followed by settling and filtration
(3) Cation Exchange
(4) Manganese Zeolite

AERATION, SETTLING, AND FILTRATION:

Both iron and manganese may be removed by aeration, settling and filtration but as manganese requires different conditions for its oxidation, the removal of ferrous bicarbonate will be considered first. *Ferrous* bicarbonate has a very appreciable solubility which varies somewhat according to the amount of free carbon dioxide present, while *ferric* hydroxide has a solubility which is so low that it is negligible. Therefore, on oxidizing ferrous bicarbonate to ferric hydroxide, the iron content of the water will be precipitated in a practically insoluble form. The oxidation is rapid and complete at pH values of 7.0 or over. At somewhat lower pH values, the oxidation proceeds at a much slower rate, so if the pH value of the water is below 7.0, it is advisable to raise it in order to assure complete oxidation and removal of the iron. This effect of pH on the speed of the reaction is clearly shown in the following table of tests with detention periods up to 60 minutes following aeration:

Table 1
EFFECT OF pH ON THE OXIDATION OF FERROUS IRON BY DISSOLVED AIR

Raw Water		Iron in Aerated and Filtered Water (ppm)		
pH	Iron (ppm)	(15 min.)	(30 min.)	(60 min.)
5.0	10.0	9.0	—	7.5
5.5	10.0	5.5	4.6	4.0
5.95	10.0	5.0	4.0	3.5
6.15	10.0	4.4	3.5	2.5
6.5	10.0	2.8	1.8	0.3
6.65	10.0	0.7	0.2	0.1
6.8	10.0	0.2	0.1	<0.1
7.0	10.0	0.1	<0.1	<0.1
7.45	10.0	0.1	<0.1	<0.1
8.05	10.0	<0.1	<0.1	<0.1

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As to the type of aerator employed, probably the most widely used type is the coke tray aerator. Wood slat tray aerators are also used and so are forced draft aerators. It is the usual practice to provide a catch basin or settling basin under or alongside the aerator with a nominal detention period of usually one-half hour or more. Occasionally, when waters have a favorable pH value, this detention period may be as little as 15 minutes. On the other hand, if the iron content is high, then it is advisable to remove the bulk of it by settling, in which case the basin should have a detention period of at least one hour.

From the catch basin or settling basin, the settled water is then passed through sand or Anthrafilt filters. The filters employed may be either of the pressure type or of the gravity type. The removal of iron by this process is very complete and the filter effluent will have an iron content of not more than 0.1 ppm.

If the iron content of the raw water is not above 1.0 ppm, settling before filtration is often dispensed with and, if the pH value is 7.0 or above, then pressure aeration, instead of open aeration, may be employed. In such cases, in order to avoid getting the water so saturated with air that it would spatter when drawn, only a portion of the water is by-passed through the pressure aerator tank and this flow is then mixed with the main flow of water. If the water, for instance is under a pressure of 60 psig., then not over 20% need be passed through the pressure aerator tank.

Unlike ferrous bicarbonate, which requires a pH value of only 7.0 or slightly over for its oxidation, manganous bicarbonate requires a pH above 10.0 unless "ripened filters" are used. If ripened filters are employed, then a pH of 8.5 to 9.0 is sufficient.

The term "ripened filters" dates back to the rather early days of manganese removal when it was noticed that when a manganese removal plant of the aeration, settling and filtration type was first put in action, apparently little or no removal of manganese occurred for the first couple of days or so and then rather rapidly the plant began to function correctly and removed the manganese. This was due

Table II

EFFECT OF pH ON THE OXIDATION OF MANGANOUS MANGANESE BY DISSOLVED AIR, WITHOUT STIRRING

Raw Water		Manganese in Aerated and Filtered Water (ppm)		
pH	Manganese (ppm.)	(15 min.)	(30 min.)	(60 min.)
8.5	10.0	---	---	10.0
9.0	10.0	---	---	9.0
9.3	10.0	8.5	8.0	7.5
9.5	10.0	7.5	5.0	3.2
9.7	10.0	3.0	1.3	0.9
9.95	10.0	0.9	0.7	0.6
10.3	10.0	<0.02	<0.02	<0.02

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to a slight coating of the higher oxides of manganese on the granules of the filter bed which seems to serve as a catalyst in oxidizing and removing the manganese from the aerated water. One bad feature of the "ripened filters" is that in time, the coatings on the filter media tend to "shell off" and contaminate the effluent. To a great extent, this tendency can be overcome by occasionally dissolving and cleaning off the old coatings before they become too thick and then "ripening" the cleaned media before returning the filter to use.

Table II shows the effect of pH in oxidizing manganous bicarbonate when no catalyst (or "ripened" filter) was employed.

While Table II shows that a pH of 10.3 was required for complete oxidation of the manganese when no catalyst was employed, Table III shows that a pH of 8.5 was sufficient when a catalyst was present. In this case, the catalyst was stirred with the water which afforded an intimate contact similar to that of a ripened filter.

The coke tray type aerator is shown in Fig. 1 and wood slat tray type aerators are shown in Figs. 2 and 3. In the first two, iron is removed by aeration and filtration before softening by zeolite to the required degree. In the third, both iron and manganese are removed by aeration, chemical softening, settling and filtration.

OXIDATION BY CHLORINE, SETTLING & FILTRATION:

Ferrous bicarbonate may be completely oxidized by chlorine at pH values as low as 5.0. While more expensive than aeration, it may be used for removing iron from waters as low as 5. pH value. Chlorine is of little

Table III

CATALYTIC EFFECT OF 1 GRAM PER LITER OF PREVIOUSLY AERATED AND PRECIPITATED MANGANIC HYDROXIDE, WITH STIRRING, ON THE OXIDATION OF MANGANOUS MANGANESE AT VARIOUS pH VALUES

Raw Water + Catalyst		Manganese in Aerated and Filtered Water (ppm)		
pH	Manganese (ppm.)	(15 min.)	(30 min.)	(60 min.)
7.5	10.0	---	---	3.0
8.0	10.0			0.3
8.5	10.0	<0.1	<0.1	<0.1
9.0	10.0	<0.1	<0.1	<0.1

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value, however, in the oxidation of manganese, unless ripened filters are employed, for otherwise a pH practically as high as for oxidation by air is required. In some experiments which I made on this, a pH of 10.0 was necessary for complete oxidation and satisfactory settling.

Both metals may be oxidized by potassium permanganate, but since this chemical is rather expensive (over 25c per pound) it has only limited applications and then only for rather small concentrations of either metal. As with the aerating processes, final removal of the higher oxides is

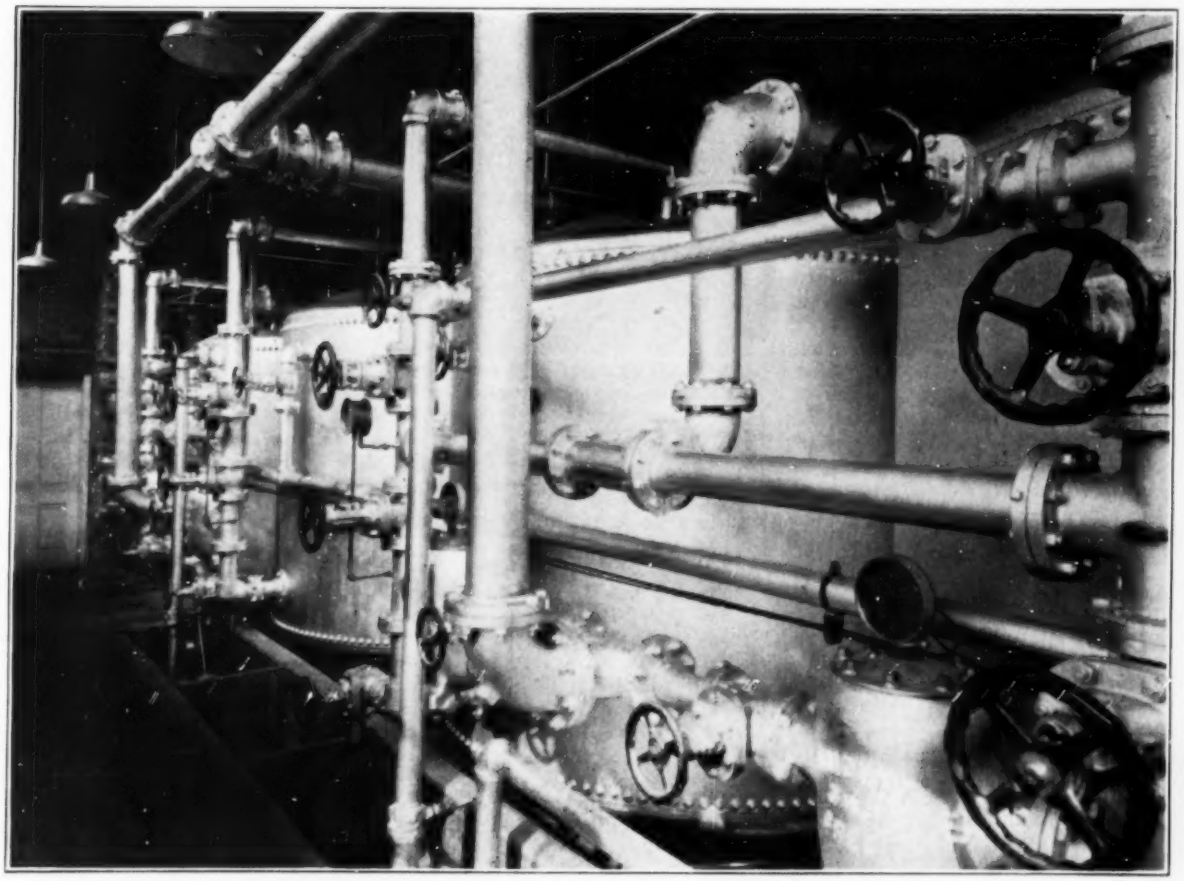


Fig. 4—ZEOLITE UNITS for combination iron and hardness removal at Wapakoneta, Ohio.

effected by (1) settling and filtration or (2) by filtration alone if the iron or manganese content of the raw water is low.

CATION EXCHANGE:

Iron or manganese in the form of the soluble, divalent bicarbonates, may be removed simultaneously with the hardness by the familiar Sodium Cation Exchange or Zeolite process. In this, the iron is taken up by the zeolite which gives up an equivalent amount of sodium in exchange for it. The zeolites which are used for this purpose are either of the greensand, carbonaceous or synthetic resin type. It is also the usual practice to limit the application of the cation exchange process to waters having not more than 1 ppm. of iron or manganese to each 2 gpg of hardness, up to a maximum of not over 10 ppm. In other words, with a water containing 10 gpg of hardness, 5 ppm of iron or manganese would be the specified maximum, while with waters having 20 or more gpg of hardness, 10 ppm of iron on manganese would be the specified maximum.

Regarding the completeness of removal of iron and/or manganese by this method, the effluent usually will not contain more than 0.1 ppm. of iron or manganese. The capacity of the Zeolite for removal of these metals extends beyond the point at which zero hardness water is produced. In other words, the softener can be overrun a certain amount and still produce an iron manganese free water. This overrun or so-called "salt starvation" method has been used to a certain extent in softening municipal water supplies where the hardness was to be reduced to 5 gpg. In such cases, usually four softeners were employed and the softening runs were staggered at timed intervals so that while one was on the overrun, the other three would still be on the softening run. Fig. 4 illustrates a 4 unit iron removal and softening plant of this type.

This method of operation, however, does not result in a mixed effluent of unvarying hardness and it has been largely superceded by another method in which one portion of the water is softened to zero hardness and the iron or manganese simultaneously removed by cation exchange while another portion of the water is treated to remove these metals but not to soften the water. For instance, in one municipality which has a deep well water containing 1 ppm of iron and 20 gpg of hardness, three-fourths of the flow is passed through 5 zeolite water softener units which remove both the hardness and the iron. The other one-fourth is passed through 2 manganese Zeolite filters which remove the iron but not the hardness, after which the two flows join through a mixing valve to produce an iron-free (0.1 ppm or less) 5 gpg hardness water.

It is important in applying this zeolite process of iron removal to keep the entering raw water from contact with air. The reason for that is that if air comes in contact with the water before it passes through the zeolite bed, some of the iron would be precipitated and filtered out by the zeolite, and the zeolite softener is not designed to act as a filter. In other words, a filter would be operated at a rate of 2 to 3 gpm. per sq. foot and would be backwashed at rates of 10 gpm. per sq. foot or over. Zeolite softeners, on the other hand, are designed to operate at flow rates of from

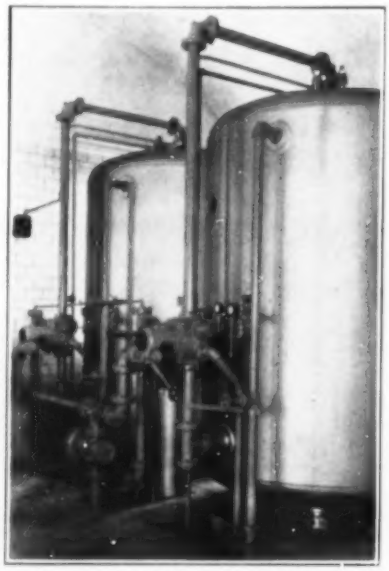


Fig. 5—MANGANESE ZEOLITE filters at East Lansing, Mich., remove iron from 25% of the water. Both iron and hardness are removed from 75%. The two portions are mixed.

5 to 8 gpm. per sq. foot and are backwashed at rates of from 5 to 6 gpm. per sq. foot.

Obviously, the iron and/or manganese may also be removed from all of the water, by aeration and filtration, before softening it to whatever degree is required. In Fig. 2, all of the water is aerated, settled and filtered before softening to the required degree with zeolite.

Cation exchangers, operating on the hydrogen (acid) cycle, will also remove iron or manganese, exchanging hydrogen for them. As these, however, are very rarely used in municipal water treatment plants, there is no need of detailing their operation.

MANGANESE ZEOLITE:

The Manganese Zeolite process is of rather limited application, but is of value in cases where the iron or manganese content is low and it is desirable to treat the water under pressure. For industrial and municipal use, it is the usual practice not to treat waters by this method unless the iron or manganese content is one ppm. or less. For household use or for rather small industrial plants, this method may be used with waters containing up to 10 ppm. of iron or manganese.

Manganese zeolite is a granular material made from greensand zeolite by alternate treatments with manganous sulfate and potassium permanganate. Its capacity for removing iron or manganese is aproximately 0.09 pounds per cubit foot and the amount of potassium permanganate required to regenerate it is 0.18 pounds per cubic foot.

In order to remove iron or manganese by this process, all that is necessary is to flow the water through the manganese zeolite filters at a rate of 3 gpm. per sq. foot. As the divalent iron or manganese comes in contact with the manganese zeolite it is oxidized to the insoluble hydrated oxide which is then removed by the filtering action of the granular bed. At intervals, it is necessary to backwash the filter to remove these deposits and the backwash rate used is 8 gpm. per square foot. Regeneration is required in order to restore the oxidizing power of the filter. Depending on the amount of iron or manganese present, the flow rate and the number of hours used per day, regeneration may be some 5 to 20 days apart. The regenerant used, as previously mentioned, is potassium permanganate, and the reason why this process is usually limited in industrial or municipal use to waters containing not over 1 ppm. of iron is because potassium permanganate is a relatively expensive material to use as a regenerate. The cost, of course, for removing small amounts of iron is not high, but with larger contents of iron, the cost would be excessive as compared with other methods. A two unit plant of this type is shown in Fig. 5.

Organic or Colloidal Iron and Manganese

In highly colored surface waters, iron or manganese is frequently present in an organic or colloidal form which cannot be completely removed by any of the foregoing processes. Some highly colored shallow well waters and more rarely a highly colored deep well water will also contain iron or manganese in this form.

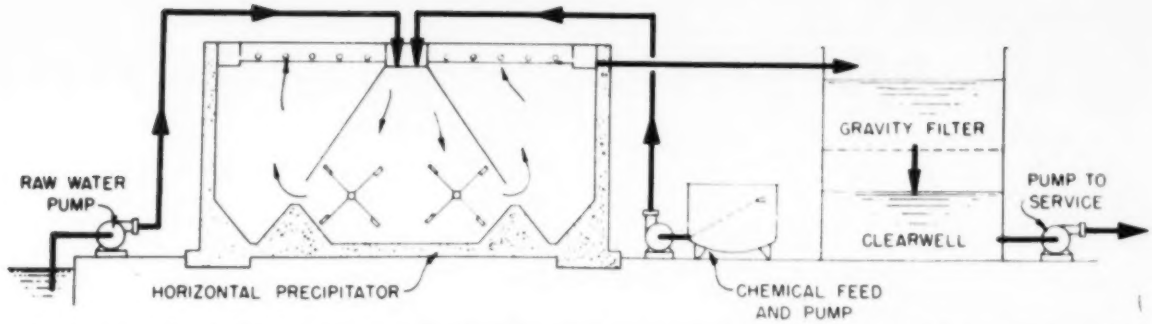


Fig. 6—FLOW DIAGRAM of Spaulding-Permutit Precipitator and filter for removal of organic or colloidal iron and/or manganese by flocculation, clarification and filtration.

In making water analyses, the iron content particularly is often expressed as "Total Iron" and then possibly a portion of this is expressed as "Soluble Iron." If the water contained only ferrous bicarbonate, then the latter figure would be rather meaningless for it would depend on whether the sample had been analyzed immediately, as drawn, or whether it had been partially or completely oxidized and precipitated during the interval between sampling and making the analysis. However, the reason for making this "Soluble Iron" determination on shipped samples is simply so that, if any soluble iron is present, then further tests can be made to see if this soluble iron is merely some which escaped oxidation or if it is due to colloidal or organic iron.

For instance, one clear but highly colored water sample with a color of 450 ppm. had a total iron content of 12 ppm all of which was in solution when the sample arrived in the laboratory some 5 days after the sample had been drawn. Aeration and filtration had absolutely no effect on the iron content even when a detention period of 48 hours was used between aeration and filtration.

Another water, with a color of 35 ppm and an iron content of 3.5 ppm was aerated, the pH was adjusted to 8.3, a detention period of one hour was allowed after which the water was filtered. This treatment only reduced the iron content to 2.6 ppm.

In another experiment in which a highly colored swamp water had 2.0 ppm. each of manganous bicarbonate and ferrous bicarbonate, both expressed as the metals, aeration plus increasing the pH to 10.5 plus one hour detention period plus filtration resulted in removing only a little less than one-half of both the iron and manganese content.

Such waters, however, usually respond to coagulation, settling and filtration which removes the iron or manganese as well as the great bulk of the color. It is advisable to run jar tests in the field, on freshly drawn samples, to find what dosage of coagulant is required, what is the most favorable pH range for coagulation and whether or not the use of a coagulant aid, such as clay or activated silica, is also required.

The coagulant usually used is aluminum sulfate as this works well at pH values somewhat below 7.0, say in the range of 5.5 to 6.8. Floc formation should be rapid and the floc should settle quickly. These tests will show what dosages and conditions are required and, under favorable conditions, the content of iron or manganese should be reduced to not more than 0.1 ppm.

The equipment used consists of chemical feeds, reaction chamber and settling equipment or precipitator and floc-former of settling basin type and filters. A flow diagram of this is shown in Fig. 6.

Ferrous Sulfate—Manganous Sulfate

In certain sections, especially in mining districts, acid waters are found —both surface and ground waters. Such waters may contain both ferrous and maganous sulfates as well as free sulfuric acid. Some of these ground waters are so heavily charged with acid and sulfates that they are not worth treating but other ground waters are amenable to treatment. As for the surface waters, the acid content has been so greatly diluted that neutralization usually offers no serious difficulties.

The usual method of treating these acid waters is to neutralize them with either soda ash or lime, aerate or chlorinate if required, settle and filter. There is usually little difficulty in oxidizing and precipitating the iron but the manganese removal may be much more difficult. Raising the pH value or using ripened filters is of value and in a few cases with surface waters where the manganese content is small, permanganate or sodium chlorite (chlorine dioxide) have been advocated to oxidize the manganese.

Beware of Low Bids!

Again, there is another instance illustrative of the fact that "the low bid may not always be the best bid"—a fact with which many a water and sewage works man has become all too familiar.

The case at point is that of Campbellsport, Wisconsin, which has recently had the sad experience of having to truck water into town for four days. The cause for this unfortunate circumstance of no water for ordinary uses, and no fire protection, was the unbelievable circumstance that the company to which the contract for repairs to the pumping equipment was awarded failed to have on hand the correct type of repair and replacement parts needed for the job.

In consequence the city had to dispatch two employees to a distant city to procure the right parts in order to complete the repairs in the quickest possible time.

Regardless of whether the company was awarded the contract on low bid or for some other reason, the lesson learned is the same. Competence and experience costs more in many instances but proves the wisest and less expensive investment in the long run.

Why Meetings?

A simple conversation across the table with a wise man of experience is worth a month's study of books. *(Could be old Chinese philosophy.)*

Practical Electricity in the Plant

ABC's of Electricity for the Water and Sewage Works Operator

by MARSDEN C. SMITH, *Chief Engr., Dept. of Public Utilities, Richmond, Va.*

Volt equals Pressure

THE VOLT is the unit of electrical *pressure*. Just as water pressure is measured in terms of pounds per square inch, electrical pressure is measured in volts. Voltage is sometimes expressed as the 'emf' which is an abbreviation of electromotive force. The usual symbol is E.

Much effort has been directed to standardizing electrical voltages (pressures), but still a "110 volt circuit" may actually range from 110 to 125 volts or even more. In fact, most residential demands supplied by public utilities as "110 volt" usually are 120 or 125 volts.

Larger current consuming devices such as ranges are built for 3-wire service; phase to neutral (ground) being "110 volts"; phase to phase being "220 volts". If the "110 volts" is actually 120 volts, then the "220 volts" becomes 240 volts.

Fractional horsepower motors usually are designed to operate from the 110 volt lighting circuits. Larger motors are available for 110, 220, 440, 2,200 and 13,200 volts. In existing installations, the voltage often is fixed by the original design; but in new installations motors up to two hundred horsepower generally are operated at either 220 or 440 volts. Larger installations warrant the advice of an experienced electrical designer to secure the best economy and safety.

Extra-heavy fittings and greater precautions are necessary when greater water pressures are used; so too, must greater care be taken both of life and property when greater electrical pressures are used. However, pressures of as little as 110 volts, in common use, *may prove fatal* and care should always be taken to avoid personal contact, especially when hands or feet are wet.

Incandescent filament electric lamps are highly sensitive to voltage change from that for which they were designed. Particularly is this true in its effect on the life of the lamp. For example; lamps rated for 110 volts and operated at 118 volts would increase the cost of lamp renewals by almost 300 per cent.

Fluorescent lamps, while not as seriously affected by over-voltage, are subject to ballast failure and rapid loss of light output if started and operated at above their voltage rating. Of particular interest to the operator is the effect of humidity and temperature on these lamps. If the room temperature is 50° F. or lower, or if the humidity is above 70 per cent, then rapid depreciation and otherwise unsatisfactory operation is to be expected.

Electric motors are not nearly so sensitive to voltage change as are lamps; nor are heating devices—particularly those that are thermostatically controlled. Motors will operate successfully at applied voltages within 10 per cent above or below their rated voltage. Greater voltage variation will generally cause excessive heating or unsatisfactory operation.

Ampere equals Rate of Flow

THE AMPERE is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally I. In print, ampere is sometimes abbreviated to "Amp."

Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamp, heating device, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. Each electrical unit (except lamps) should have its normal current rating stamped upon its name plate. Lamp current is approximately determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus, currents to this extent are standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should *never* permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance in a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current nearer the source of power. For example: Five 1,000 watt lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and and the first (No. 1) lamp carry 50 ampres; between 1 and 2, 40 ampres, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Ohm equals Resistance

THE OHM is the unit of electrical *resistance*. In equations its symbol is R.

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current amperes can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact is distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed later) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \qquad (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Watt equals Power

THE WATT is the unit of electrical *power*. The most commonly used unit is the Killowatt, which is one thousand watts. The symbol for the Watt is W; for the Kilowatt KW. The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \qquad (2)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \qquad (3)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \qquad (4)$$

Now it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

Direct and Alternating Current

Formula (1) applies only to circuits that contain nothing but resistance, no inductance or capacity; or those circuits in which the "frequency" is zero. If two wires A and B are left connected to the terminals of a battery the current flow in the wires will be in one direction, thus becoming a "direct current" (unidirectional current). Such circuits usually are referred to as D.C. circuits and include battery supplied devices. These circuits are seldom used for public power except in limited areas of older cities.

If now we reverse the connections of the two wires each ½ second, then the current will flow in one direction for ½ second, but will flow in the reverse direction during the next ½ second. Obviously the current will then flow in the same direction in the same wire commencing once each second. Such a circuit would be defined as an "alternating current" (or voltage, or circuit) having a *frequency* of one *cycle* per second. Thus it is evident that "frequency" is the number of "cycles" per second, or ½ of the number of times the current flow reverses in each second.

The almost universal standard frequency is now 60 cycles per second, and the time-potential value of the voltage closely follows the sine law. This latter fact permits the use of vectors in the solution of alternating current problems, but such solutions are beyond the scope of these notes.

If a direct current is caused to flow thru a coil of wire having a resistance of R ohms, wound around an iron core, then—since the frequency is zero—formula (1) can be used. But if the current is made alternating the value of R seems to increase more and more as the frequency is increased. This is because the coil and its iron core form an "inductance" the nature of which is mechanically similar to a heavy fly-wheel. Inductance opposes any change of current flow and thus prevents the current from being proportional to the voltage (roughly speaking). If the coil has no resistance (academic assumption) then this inductive effect would cause the current to lag 90° behind the voltage causing it to flow. Parenthetically, "capacity" (insulated plates or parallel wires), which is an effect negligible in water plant installations, causes the current to lead the voltage by 90°. Thus, if the capacity effect is equal to the inductive effect, these cancel and the circuit behaves as if it contained neither capacity nor inductance.

Thus in an alternating current circuit, equation (1) becomes:

$$E = ZI \quad \ldots\ldots (5)$$

in which Z is the *impedance* of the circuit and its value is expressed in ohms.

Many electrical appliances, including heating appliances and lamps have little if any magnetic effect (hence little inductance) and so may be used equally well in alternating or direct current circuits. Motors must be of a special design if they are to be used on both AC and DC circuits; and transformers must never be connected to DC supplies.

Power Factor

The above equation (2) is generally used in the form:

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In which the COS θ is the *power factor* of the circuit, sometimes abbreviated PF. The angle θ is the time displacement between the voltage and the current which, as has been shown, is determined by the relative values of resistance and the inductive and capacity effect in the circuit. Since this may (theoretically) be of any value between zero and 90°, the power factor may have any value between zero and one.

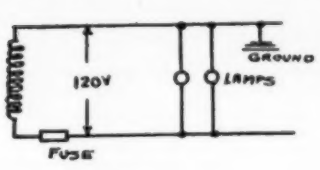


FIG 1

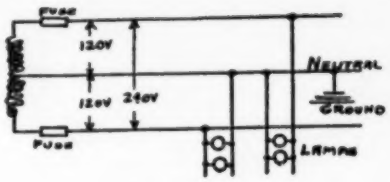


FIG 2

Circuit diagram—Figs. 1 and 2

The actual mathematical value of the power factor of circuits is difficult to compute, but may be readily determined by an instrument designed for the purpose or by the simultaneous readings of power, voltage and current by means of a wattmeter, voltmeter and ammeter.

As has been stated, the PF of heating appliances and lamps is quite nearly unity.

The PF of motors and transformers vary through rather wide limits, being nearly zero for transformers at no load. As their name implies, induction motors also have relatively bad power factors, small units being as low as 60 per cent at light loads and large motors of this type at full load not over 94 per cent.

Synchronous motors may operate at from 60 per cent lagging to the same value leading, thus cancelling the low PF of inductive units on the same circuit.

Low power factors are serious because of the greater current required for the same power, thus increasing the power loss in the wiring of the power supply. The effect on the constancy of voltage is also quite serious; in fact power companies frequently offer reduced rates to encourage the use of high power factor equipment.

Obviously the operator can do but little to improve the power factor of his system except in the selection of the type of motor, as more fully discussed later.

The Kilowatt-Hour

The kilowatt hour is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at an average rating of 600 watts, there is used 600 x 2 = 1200 watt-hours, or 1,2 KwHrs.

The volt ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in volt-amperes (VA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load determines its power output. Thus we see that:

$$KW = Kva \times \cos \theta \quad \ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume one-half of the load to be lamps and one-half small motors, we may approximate the average power-factor as 82 per cent. Hence, by equation (7) we find Kw = 100 x 0.82 or 82 Kw to be the safe load for this case.

Grounding

Grounding is the connection of one wire of an electric system or any metallic part of the system to the earth.

All alternating circuits must be grounded, and the grounded wire is called the *ground* or *neutral*: the wires not grounded are called the *hot* or *phase* wires. The neutral is the point of equal potential to the phase wires (See Figs. 2 and 4). The neutral of Fig. 3 is neutral to the two bottom but not the upper phase wire. If there were no ground of the transformer neutral or of the phase wires in Fig. 3, the neutral would be an imaginery point.

The ground must be equal in size or larger than the phase wires; and it must not be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

The approved maximum voltage to ground for any wire connected to standard "house-wiring" switches and receptacles is 150 volts. This is why only one phase of a 220 volt delta system may be used for the lighting circuits. Where greater voltage exists for motors etc., the wires must be enclosed in a metal conduit and the frames of the motors and conduit system electrically connected and grounded. Grounding should be carefully inspected at sufficiently frequent intervals to make certain that the essential protection it provides is in perfect condition.

Grounds should be carefully made, preferably use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼ inch pipe, or equivalent copper rods, *well*

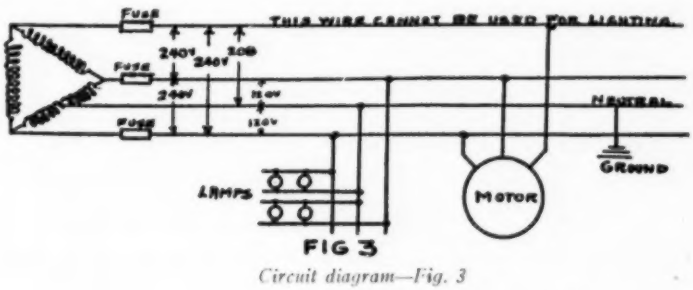


FIG 3

Circuit diagram—Fig. 3

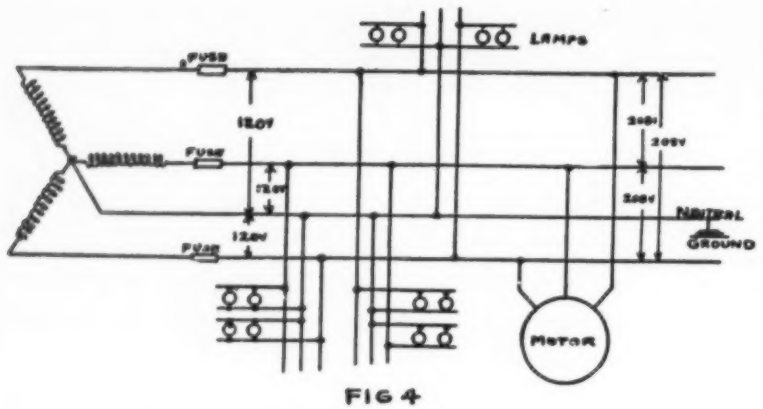


FIG 4

Circuit diagram—Fig. 4

below the moisture line in the earth. A good test is that the driven ground connection, when sorted, should blow a 30 ampere fuse at 120 volts.

The necessity for grounding the electric circuits is to prevent dangerous high potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous value. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire would be started, or perhaps a member of your family would be killed. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have prevented.

Phase

Phase is a term also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart and in the "Three-Phase" system they are 120 degrees apart.

In another sense, it may be considered that there are in effect one or two or three circuits in the single, the two or the three phase systems. Of course the load and power factor in the different phases may differ, and hence the computation of power in polyphase circuits becomes difficult and beyond the limits of these fundamentals.

Circuits

The single phase, two-wire circuit shown in Fig. 1 is the simplest and most used connection. As seen in figures 2 to 4, it is the connection used to supply lamps and small motors and appliances in even the largest systems.

The single phase, three-wire circuit shown in figure 2 is really two single phase circuits with one wire in common. It is used when more power is needed than can economically be supplied by the two-wire system; also it permits "220 volt" units to be connected to the two fused wires and yet the system has no more than 110 volts to ground. When the loads are identical the neutral wire carries no current, but since one fuse may *blow* (melt) the neutral must carry the same current as the phase wires and hence must be of the same size. But even then this system saves one of the four wires that would be required for two two-wire circuits.

The three phase circuits shown in Figs. 3 and 4 are really three single phase circuits connected together, with the important difference that the three phases are equally spaced in time relationship (120° apart). There are two connections generally used for three phase circuits, the "Y" and the "delta," each of which has certain advantages. In general the "delta" is more reliable, when used for power only, in that if one transformer is lost the remaining two can supply 87 percent of their combined capacity. But to off-set this when lighting is needed, unless the motor load is small enough to be operated at 110 volts, one of the neutrals of one of the transformers must be grounded, thus increasing the chances for power failure.

Then too, many power companies will limit the lighting load that may be placed on the one phase supplying it (see Fig. 3); and the lighting is badly affected with "flickering" particularly if the motors are frequently started and stopped as for elevators.

The "Y" connection has the advantage that the lighting load can be divided between the three phases, but the three-phase voltage for motor use is less than that for which motors are usually designed.

Hence it may be said that for large loads three phase systems are always used. In one water treatment plant the lighting and motors of less than 5 HP are supplied by three "Y" connected transformers; the large motors and elevators are supplied from three DELTA connected (480 volt) transformers.

The formula for power in the different systems, with equal load and PF, is given in the Table 1.

Table 1

System	Power		Max Volts to Ground
Single-Phase (Two Wire)	$P = EI\cos\theta$	Here $E = 120$	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here $E = 240$	120
Two-Phase (Four Wire)	$P = 2EI\cos\theta$	Here $E = 120$	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here $E = 240$	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here $E = 207.8$	120

* Volts to ground on lighting circuits is 120.
The two-phase (four wire) system is so little used that no discussion is necessary.

Fuses and Circuit Breakers

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. The National Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable fameproof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type known as the "refillable type," permits the renewal of the fuse link and the use of the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker may be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of a circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are only three:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given overcurrent can be selected as desired. The oil

in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type.* Here an air bellows with an adjustable escape valve is used in place of the oil dash-pot described above. This type is now essentially obsolete.

(3) *The Induction Type.* This relay is more expensive than those above mentioned, but its use is justified in the protection of all important circuits. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Overfusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. A too frequent operation of the overload protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of enlarging the circuit protection.

Motors

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences which will be mentioned later.

Synchronous Type Motors

At a given frequency the speed of a synchronous motor may be determined by the equation:

$$N = \frac{120f}{P} \quad \ldots\ldots(8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots(9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900 . . . RPM. One of the greatest limitations of the standard synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are less desirable. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps frequently may be started without inconvenience, which renders this deficiency of the synchronous motor less serious.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements constitute a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above discussion, it can be seen why the use of synchronous motors is frequently advised against for water works and sewage treatment plant use. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operate difficulties that are certain to be realized in the use of synchronous motors.

Induction Type Motors

The induction motor differs from the synchronous type in that it requires no separate excitation and it operates at a variable speed, as contrasted to the constant speed synchronous motor.

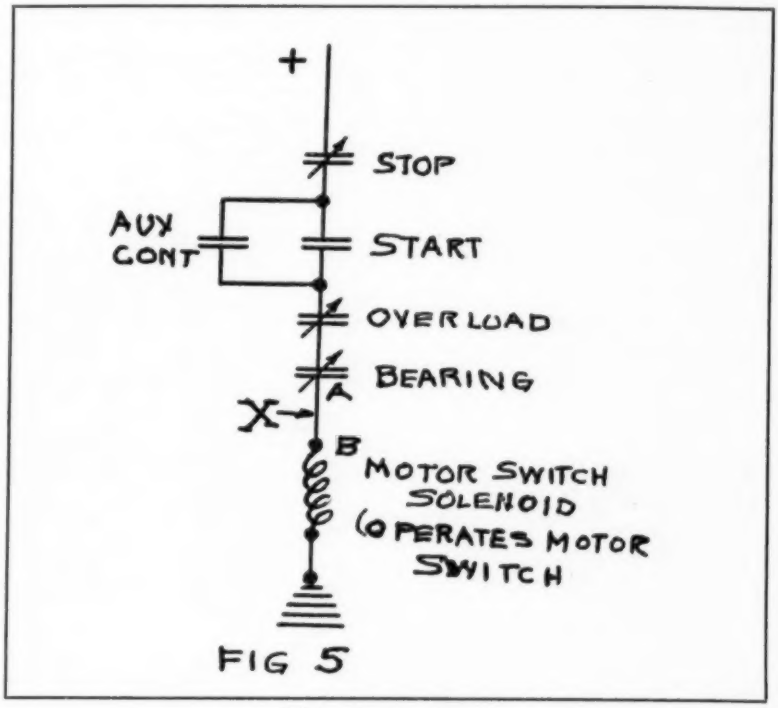
At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four, or any even number of poles, just as is the stator of a synchronous motor; hence, it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced by two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the slip (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the pull-out load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But, while they will operate successfully under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may



Wiring diagram—Fig. 5

be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is usually obtained from auto-transformers, called *starting compensators*. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage applied to the motor terminals.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not as rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble.

We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of slip. As stated above, the standard squirrel-cage motor slip varies from virtually nothing at no load to about 3 per cent at full load. With the wound motor, external resistance may be added to the rotor circuit, the effect of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed be reduced.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of transformers is advisable. The standard transformer consists of two stationary coils of wire, insulated from each other and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

The coil or the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase as readily as to reduce the voltage. Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead" when in fact the 110 volt side was still energized, *thus producing normal high voltage in the primary.*

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, *if kept cool*, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation may effectively cool transformers submerged in oil, but hot weather and hot locations are dangerous. Oil tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

Ratings

The rating of most units of electrical apparatus—such as motors, transformers, etc. —is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while others base their estimates upon a rise of only forty degrees. After all, this simply means that a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degrees rise. All things considered, it seems to be the consensus of opinion, and a wise dictate, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise of not to exceed forty degrees centigrade.

Circuit Wiring Diagrams

The remote and automatic control of electric motor driven pumps and other electrical equipment now requires that the operator be familiar with the diagrams that should always be available for repair and maintenance of such circuits. Most non-electrical people feel that a wiring diagram is too involved for them to understand. It is really surprising how simple a wiring diagram can be—if it is complicated, it is unnecessarily so.

In Fig. 5 a simple remote motor control circuit is shown. Note first that the circuit is complete and that the contacts must carry the current required by the solenoid, since they are in series with the solenoid.

Contacts that normally are closed *before starting* are marked with an arrow. Since all contacts except *start* are closed all that is needed to start the motor is to close the *start switch* (press start button). But, since that switch must open as soon as pressure is removed, an auxiliary contact must be provided which closes when motor switch closes.

When the auxiliary contact is closed the circuit is completed even with the *start switch* open, and so the motor continues to run until something causes the control circuit to become "opened." Normally this would be done by pushing the *stop* button opening the *stop* switch. But if a bearing overheats, or if the motor is overloaded, then the opening of either of these switches will also open the circuit; thus deenergizing the motor switch solenoid, opening the motor switch, and stopping the motor. Now assume that the wire breaks, thus opening the circuit, or that a bare wire touches "ground" at "X." The nature of the trouble could be determined by (a) blower fuse (short) indicating bare wire touching; or (b) voltage indicated by test lamp to be at A but not at B. All wiring diagrams are nothing more than elaborations of this simple circuit and certainly are within the grasp of anyone willing to figure them out.

Wires

Because of the dampness normally existing in water and sewage plants, money invested in adequate conductor protection is wisely invested.

For important circuits, 1000 volt rubber insulation is recommended to carry up to 440 volts. For higher volts, an insulation of at least twice the operating value is good practice. Varnished cambric and paper insultions are suitable for central stations and distribution cables, but their use in water and sewage plants is not advised for circuits of 2200 volts or less.

The covering of the insulation should be carefully selected to meet conditions of mechanical abrasion, oil or other chemical exposure. "Neoprene" is highly successful except for high temperature locations, and is now widely used as the outer covering of insulated wires and cables.

Allegheny County Plant to be Largest in U. S.

The Allegheny County Sanitary Authority is ready to start construction of a $70,000,000 sewage disposal plant on the Ohio River within a year, the Ohio River Valley Water Sanitation Commission was told at a recent public hearing.

This project, along with one at Wheeling, W. Va., which will break ground this fall for a $7,500,000 sewage system, and the move by Cincinnati to begin operation of a $5,000,000 treatment plant, it was said, will have a major effect in promoting purification of the 1,000-mile length of the Ohio River.

H. E. Moses, consulting engineer of the Pennsylvania Department of Health and a commission member, told the hearing that the state would be considering final plans for Allegheny County's sewage disposal project in August.

The sewage system to take care of disposal from Pittsburgh and sixty-four other communities in Allegheny County will be the largest single project of its kind in the country, Mr. Moses said. He expected that the system would be ready for use in the spring of 1957.

WATER WORKS PRACTICES

OPERATION • MAINTENANCE • MANAGEMENT

History of Water Supply 1850 to Present

The Third of a Series

by GEORGE E. SYMONS, Ph.D., *Consultant & Technical Editor, Larchmont, N.Y.*

CONTINUING the practice of answering pertinent questions on previous lectures, here are two:
Q. Is the boiling point of water constant?
A. No—At sea level or standard conditions of atmospheric pressure (760 mm of mecury), the boiling point of pure water is 100 deg. C or 212 deg. F. As pressure is lowered, the boiling point drops. This explains why at high elevations (where the barometric pressure is less than at sea level) it takes longer to cook a boiled egg or potatoes. At 5000 ft. the boiling point of water is 203.1 deg. F. and at 10,000 ft., the boiling point is 193.9 deg. F. The presence of considerable amounts of dissolved minerals will make the boiling point of water increase.
Q. Is the feeezing point of water constant?
A. Under normal conditions of atmospheric pressure, water will freeze at 0 deg. C or 32 deg. F, but it is possible to supercool water to 29 or 28 deg. F (or lower) without freezing, if the water is cooled *without* any movement of the water. The slightest movement of supercooled water will cause instant freezing to begin.

This article is one of a series on the general subject of "Water Works Practices." Each article has been developed by Dr. Symons from his notes for a Water Works Short Course and each is presented in the simple style of a short course lecture. The series has been designed to be of interest and aid to small plant operators, new operators, students, and any who may wish to review the fundamentals of water works practices.—The Editors.

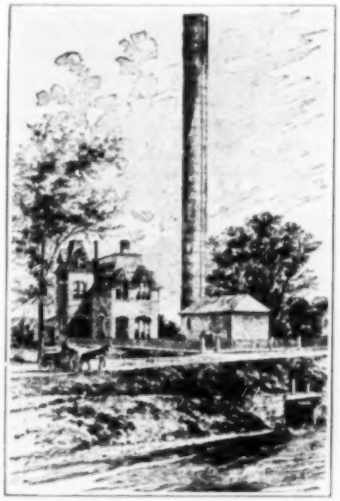
Modern History—1850 to Date

1. Plain Sedimentation

a. Although plain sedimentation in small vessels had been practiced by the ancients, its use on turbid river waters dates to the early 1800's, notably the annular ring shaped basin at Paisley, Scotland, (see p. 96 W.&S.W. March 1953) and Happey's basins in Paris.

b. Lynchburg, Va., was the site of the first U.S. settling basin in 1829. It was designed by Albert Stein, the man who designed the ill-fated Richmond, Va. plant three years later.

c. Not too many plain settling reservoirs were installed in America.



EARLIEST mechanical water filters for a public supply are believed to have been those of Somerville, N.J. installed in 1885.

(The Hyatt Patented Pure Water Filter used is pictured on the next page.)

Records indicate installations in Quebec, Can., in 1848; in West Chester, Pa., in 1854; and in Kansas City, Mo., in 1874.

2. Coagulation and Sedimentation

a. The art of coagulation goes back to ancient times; early Egyptians employed crushed almonds; in India crushed nuts were used; in China, alum.

b. First modern mention of alum coagulation was in England about 1757 and the process was used in the early 1800's for industrial supplies, but as late as the 1840's people had a horror of adding "foreign matter" to water supplies even though they were turbid and polluted.

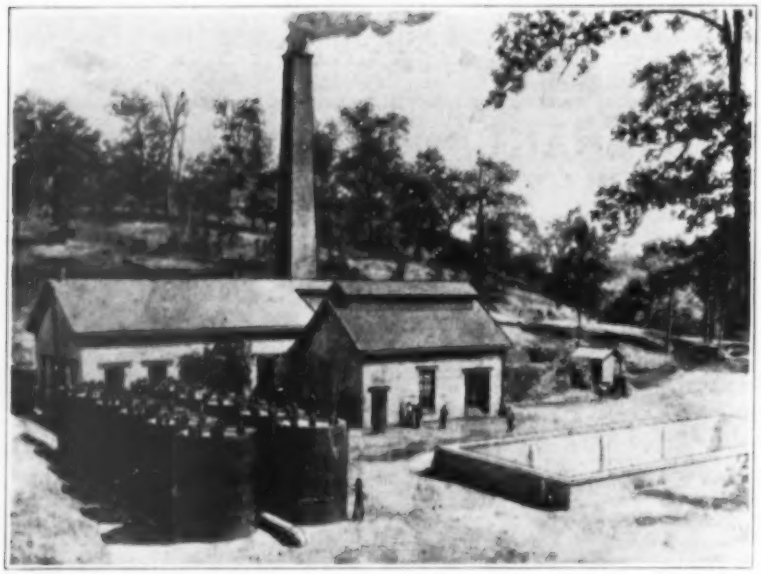
c. Not until the late 1800's was coagulation adopted, principally as the result of American studies. Coagulation was the first "gift" of American engineers to the science of water treatment.

d. First American public water supply to adopt coagulation was the Somerville and Raritan, N.J. Water Co., in 1885 and this treatment was employed in connection with the Hyatt Filter installation. That same year Rutgers University published the first scientific treatise on alum coagulation.

e. Other early pioneers in coagulation included Vicksburg, Miss., in 1887-88 where one grain per gallon of alum was used. Omaha, Neb., adopted coagulation in 1899; Chester, Pa., in 1901 and Kansas City, Mo. in 1902.

f. Iron or iron salts were proposed as coagulants in the late 1800's with or without lime. St. Louis, Mo., was the first American city to employ ferrous sulfate and lime in 1904 to provide a water pleasing to visitors attending the St. Louis World's Fair.

g. Lime alone had been used for chemical coagulation of sewage in England prior to 1900 but it was



ATLANTA'S 3 mgd. plant, believed to be the first large mechanical filter installation by a municipal water works.

(Reproduced from an old wood-cut illustrating the catalog of The Hyatt Pure Water Co., this picture shows the twelve units which are still standing)

never adopted for water treatment, until used principally for softening.

h. In 1893, the Lawrence Experiment Sta. of the Mass. State Board of Health studied chemical coagulation. Then as the result of the classic experiments of Fuller and co-workers at Louisville, Ky., in 1895-97 (see group photo), coagulation and rapid sand filtration became standard American practices.

3. Filtration

a. At the time when filtration was becoming established in the mid-19th century, a German chemist, Forschammer, developed the first test for water pollution. It was the forerunner of the modern oxygen consumed from permanganate test and employed that reagent. This test was the forerunner, too, of several chemical tests which came into use before the discovery of bacteria.

b. First known American filter which worked was the charcoal, sand and gravel filter in Elizabeth, N.J., installed in 1855.

——— First slow sand filter was that of Poughkeepsie, N.Y., in 1872. By 1900 there were only 20 slow sand filters in the U.S. and now are probably no more than a hundred. The Poughkeepsie filter was built from the designs submitted by James P. Kirkwood in his famous report of 1869 to the City of St. Louis, which rejected his plan.

c. Rapid or mechanical filtration was the second great contribution of American engineers to the art and science of water supply and treatment. It was called mechanical filtration in the decade from 1890-1900 because the beds were cleaned by mechanical means rather than by hand as in slow sand filters. Gradually the name rapid sand filter came to be common just as the English filter came to be known as the slow sand filter.

d. Early mechanical rapid sand filters bore such names as Clark, Hyatt, Newark Filter (Hyatt patents), National, American, Jewell and Continental. The Clark filter had a jet surface wash, and the National, of which there was one at Champaign, Ill. in 1887, had a double wash system. By the end of the century, consolidation or failure had left but one name, the New York Continental Jewell Filter Co., but that too passed out of the business picture and today the names in filter business include Builders-Providence, Permutit Co., Roberts Filter Co., American Water Softener Co., E. W. Bacharach Inc., and International Filter Co.

e. Famous names in filtration history include that of Allen Hazen, who was Chief Chemist of the Lawrence Expt. Sta. during the filtration experiments there and his treatise on filtration in 1895 was not only pioneering, but was a classic report.

——— Another famous name in filtration is that of George Warren Fuller (whose memory is honored by the A.W.W.A. Fuller Memorial Awards). Fuller was Chief Chemist of the Louisville Water Co. and with the aid of Robert Spurr Weston, Joseph W. Ellms and George A. Johnson (three other famous names in water supply) and others, he conducted the famous coagulation and filtration experiments at Louisville, Ky. in 1895-97. It was those studies which set the pattern for modern practice of sedimentation of coagulated water followed by filtration.

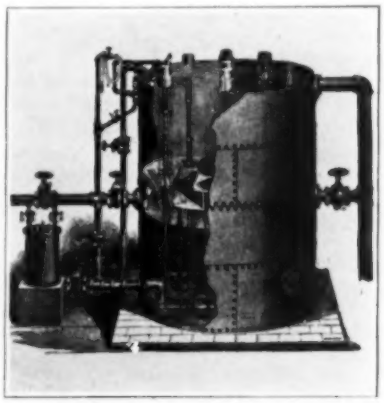
f. Other filter systems included: (1) Upward Filtration, (2) Multiple Filtration, (3) Drifting Sand Filtration, and (4) Infiltration Galleries.

——— Upward filtration generally failed but the idea was revived in England in the 1920's.

——— Multiple filtration, particularly the Peuch-Chabal system, had many installations in France. This system included roughing filters, pre-filters and final filters, with the filtering material decreasing in size and the filter rate decreasing in the successive stages.

———Drifting sand filters took sand from the bottom of the filter and ejected it to the top, washing it on the way. Toronto, Can. installed filters of this type in 1918.

——— Natural filters or infiltration galleries were usually built alongside of rivers in sand and gravel deposits. A number of such installations were made in America; some are still in use. A possible revival of this form of treatment is seen in proposals for recharging ground water supplies through gravel beds. The Ranney well, with its well points radiating from a central collecting well, is a modern form of infiltration gallery.



ORIGINAL Patented "Hyatt Pure Water Filter" which was installed at the Somerville, N.J. plant 1885 and in Atlanta, Ga. 1887.

Alum coagulation, as an aid to mechanical filtration, was first employed at Somerville, N.J. (1885); Atlanta Ga. (1887); Chattanooga, Tenn., (1888).

4. Disinfection

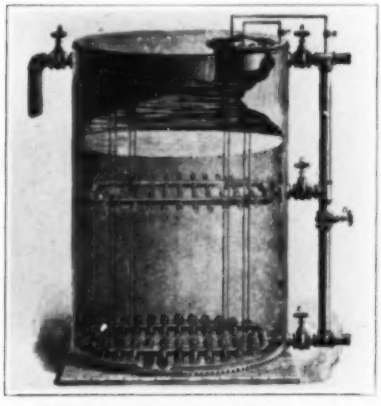
a. Disinfection (germ killing) by chlorination was the third great contribution of American engineers to water supply practice.

b. Disinfection by boiling, use of copper vessels, etc., had been practiced by the ancients, and there were many patented processes for disinfection in the latter half of the 19th century, including that of Prof. Leeds of Stevens Institute in 1888 for the chlorination of water. Electrolysis to produce chlorine from salt brine was tried in Louisville in 1896 but the idea was soon dropped.

c. Bleaching powder, which was invented in 1894, was first used to chlorinate water in 1896 in Austria and it was also temporarily used in Adrian, Mich. in 1899. The first continuous water chlorination plant in the world was in Belgium in 1902, using chloride of lime. Lincoln, Eng. was second in 1905, under direction of Sir Alexander Houston, famous British water chemist.

d. It was not until 1908, however, that water chlorination became a reality. That was when the process was applied by Geo. A. Johnston, of Louisville fame, at the Bubbly Creek Filter Plant of the Union Stock Yards in Chicago and at the large installation at Boonton Reservoir of Jersey City, N.J. in the same year under the supervision of Geo. A. Johnson.

e. Liquid chlorine was first produced in 1909 and was used in 1910 by Major Darnall of the U.S.A. Med. Corps at Fort Meyer, Va. Solution feed in which chlorine gas was dissolved in water was under experimentation by Dr. Georg Ornstein of the Electro Bleaching Gas Co. in 1911 and the first full scale application of solution feed was made in Niagara Falls, N.Y. in 1912.



SURFACE WASH was a highly advertised feature of National Water Purifying Cos. patented filter.

"Economy Through Surface Wash" was the principal sales argument. National Filters were installed by the Chattanooga (Tenn.) Water Co. in 1888.

LOUISVILLE, KY. Experimental Filter Station staff that made water purification history in 1896.

George W. Fuller, chief chemist and bacteriologist looking akin to "Teddy" Roosevelt, is the central figure. Others in the picture also became famed water and sewage experts. Upper row—Robert Spurr Weston; "Willum"—the janitor; George A. Johnson*; Harold C. Stevens. Lower row—R. E. Bakenhus; Joseph W. Ellms*; C. L. Parmelee; George W. Fuller*; Hibbert Hill; N. N. Benton.*

*(*Names which subsequently became famous in the water and sewage field.)*

f. Commercial equipment development followed with the work of John A. Kienle at Wilmington, Del., Dr. Ornstein for Electro Bleaching Gas Co. and the now famous team of C. F. Wallace and M. F. Tiernan who built their first chlorine gas feeder for Dover, N.J., where it went into operation in Feb. 1913. This was followed by the W & T solution feeders, which have grown in size, complexity, performing ability and number of installations ever since. Other names in chlorine feeders over the years have included Pardee, Chemco, Everson and, most recently, Builders-Providence.

g. Very few cities in the United States do not chlorinate the water supply and the dramatic drop in typhoid fever death rates following 1912-13 presented vivid proof of the efficacy of chlorination.

h. Ozonation of water supplies began about the same time as chlorination, but the number of installations was small in this country although there were several in Europe. Latest use for ozone is for taste and odor control.

i. Ultraviolet rays have been used in a few installations, mostly in France. Four American cities tried the treatment between 1915-1930 but most were abandoned. Some industrial installations still exist in the U.S.

5. Taste and Odor Removal

a. Slow sand filters in England produced water of high clarity and free of tastes and odors. Rapid sand filters plus chlorination often increased tastes and odors, particularly where small amounts of phenol were present from industrial wastes.

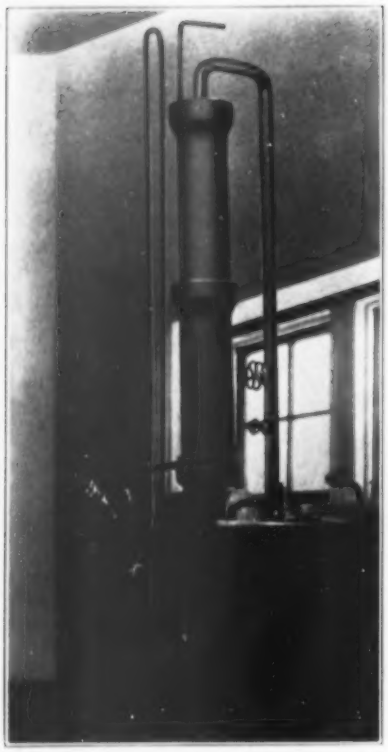
b. Aeration was, and still is, practiced for taste and odor control but it is only partly successful, particularly where heavy algae growths or industrial wastes exist.

c. Control of algae in reservoirs by addition of copper sulfate began between 1900 and 1910 and prechlorination for taste and odor control was introduced after 1925. Use of ammonium compounds and free residual (super) chlorination followed in the thirties.

d. Addition of activated carbon for taste and odor removal began about 1929-30 and has been the most popular treatment for that problem ever since.

6. Softening

a. Addition of lime to water to remove hardness dates from Prof. Thomas Clark at Aberdeen University in 1841. About 30 years later, John Porter, a London Civil Engineer, added soda ash (sodium car-



EARLIEST solution feed chlorinator employing liquified chlorine gas—a novelty at the time.

This unit developed by Dr. Georg Ornstein for The Electro-Bleaching Gas Co. went into service at the Niagara Falls plant of the Western N.Y. Water Co. Nov. 14, 1912.

bonate) to remove non-carbonate (sulfate) hardness and thus the Porter-Clark (lime-soda) softening process came into being.

b. Softening plants grew slowly in number until about 1930, when evidence showed that the cost of soap wasted by hard waters would more than pay the cost of the softening process.

c. The art of "upflow contact precipitation" or sludge blanket clarification really began in 1869 when it was first used in chemical sewage treatment by Sillar and Wigner.

——— The most important early sludge blanket clarifier was that patented by Archbutt and Deeley in 1892 and the process was called "Accelerated Precipitation."

——— Sludge blanket clarification became a modern day treatment in 1935 with the development by Spaulding of the "Precipitator," later taken over by the Permutit Co. Other modern sludge blanket clarifiers include Infilco's "Accelator," Dorrco's "Hydrotreator," Chain Belt's "Vertiflo," Graver's "Reactivator," Walker's "Clariflow," and American Well Works' "Flocsettler."

d. "Cation Exchange Process" is the term now properly applied to water treatment formerly known as "Zeolite Softening." Zeolites first received attention as "water softeners" in the first decade of the 20th Century. In 1910, New Jersey "Greensand" was patented for use as a water softener which operates on the principle of exchanging "soft" sodium for "hard" calcium and magnesium in the water, thereby "softening" the water.

——— In the 1930's came the synthetic "gels" and modern high capacity synthetic resins with the ability to treat large volumes of water at rapid rates and to be regenerated quickly. Early use of cation exchange softening was for industrial water supplies, but some 160 municipal "Cation Exchange" softening plants have been installed; some of these are automatic in their regeneration and washing cycles.

e. With the advent of synthetic detergents or "soapless soaps" in large quantities after 1940, the pressure from domestic water users for soft water seems to have eased off. There are now probably more than 700 municipal softening plants of all kinds.

7. Fluoridation

a. Fourth great innovation in water supply engineering in America was the introduction of fluoridation. Strictly speaking, this is not a water treatment process; neither is it mass medication; but by the addition of one ppm of fluoride ion to water supplies, the dental health of children is greatly improved in that the number of decayed, missing and filled teeth decreases.

b. First experimental installations were at Grand Rapids, Mich., and at Newburgh, N.Y. in 1945. Both cities have shown marked reduction in dental decay in children born since 1945, when compared to similar groups of children not receiving fluoridated water.

c. According to the Washington Health Council, in January 1952 160 communities were using the fluoridation process. In January 1953 the number had grown to 453 with some 400 other municipalities having approved fluoridation and installing equipment.

——— Use of fluoridation depends on its advocacy by the dental and medical societies in local areas. Water Works Operators merely cooperate in adding the desired amount of fluoride compounds; they do not promote the practice.

8. Iron and Manganese Removal

Both iron and manganese have long been recognized as undesirable in water supplies and removal of iron dates from 1893; the first plant scale experiments on manganese removal were conducted between 1911 and 1915 by the Illinois State Water Survey under Dr. Bartow.

9. Summary

a. A century and a half spans the art of filtration; a hundred years encompasses the development of modern practices; six decades cover the subject of coagulation; four decades cover disinfection and water polishing (taste and odor control); and fluoridation is less than ten years old.

b. For such an important commodity, so vital to life throughout the history of mankind, its purification for the benefit of man covers a painfully short period. The greatest advances have occurred practically since the beginning of this century.

c. To persons who are historically minded and like to delve into the details of the past, I recommend, *"The Quest for Pure Water,"* by N. M. Baker, published by the Amer. Water Works Assn. in 1948. An excellent review of chlorination history by Harry A. Faber, appeared in *Water & Sewage Works* in November 1952.

Next Lecture—The Hydrologic Cycle.

W. & T. stands for C. F. (Fred) Wallace and M.F. (Mike) Tiernan who made water purification history with their inventions.

In this picture, the team of inventor Wallace and salesman Tiernan with their first dry gas feed W & T Chlorinator. This unit, since museumized, was put in service by their own hands on Feb. 22, 1913 at Dover, N.J.

How Does Industry Make a Pollution and Waste Survey?

by J. E. COOPER, *Partner, Du Bois-Cooper Associates, Detroit, Michigan*

WASTE surveys in industry vary widely in scope and detail and it is the purpose of this paper to describe some of the considerations which should be taken into account when such a survey is to be undertaken.

In this writer's experience survey methods vary somewhat, based on whether they are made by the staff of the company to be studied, or by a governmental regulatory agency. It is the intent of the writer, therefore, to comment on such surveys assuming that the survey will be carried out by industry personnel.

How some industries make surveys often differs greatly from *how they should* investigate their wastes. Too often, for example, much attention is focused on the measurement of the volume of waste water and partial analysis of samples of same, rather than making a more thorough, exacting study of internal industrial operations which, in most cases, proves a more reliable indicator of the potential pollution threat.

The right combination of efforts expended in the various directions which an Industrial Waste Survey might take, can only result from a careful evaluation of all factors involved.

Great emphasis should be placed on the initial planing of any surveys. This is obviously elementary but often overlooked.

Organization for a Survey

To initiate a survey, those in charge should first very carefully delineate the scope of the investigation. They should consider:

(a) The use to which the facts learned shall be put.

(b) Whether the study will include not only the wastes from the industrial plant operation, but also their effect on the existing receiving water, sewer system or sewage treatment plant.

(c) Whether the investigation will be completely "private", that is, within the industry, or whether it is to be "cooperative" and one or more of the local, state, or Federal pollution control agencies invited to participate.

(d) The availability of trained personnel, and special equipment (engineers, chemists, laboratory, instruments, etc.)

If the survey is to be of such a comprehensive nature as to include an evaluation of the effects of the wastes on the receiving waters, sewer system, or sewage treatment plant, certainly one or more preliminary surveys are in order to provide information on approximate wastes flows and volume of the various types of material to be encountered etc.

Cooperative Undertakings Advisable

Further, the best advice possible, is to invite the regulatory agency involved to sit in on the planning phase of the survey and, if possible, take part in same. This latter course is often approached with a "dim view" by many industrial managements, but an increasing number of enlightened executives have come to recognize that the facts which the survey will disclose are more apt to be complete, correct, and unquestioned by such regulatory agencies during any subsequent action.

It is important to remember too, that any use of the experience and assistance of local, State and Federal agencies in making a survey, in no way usurps the prerogatives of Industrial Management who, in the end, retain their right of final disposition of the facts. A survey is a fact-finding study, no more than that. Subsequent use of the facts or action is a different phase of industrial waste control and becomes the responsibility of the management, not the technical staff. "Agency-Industry" co-operation during a waste survey is usually the initial "working together" phase between technical staffs of both Agency and Industry and is highly beneficial to all concerned.

When the survey data is to be used as the basis for the design of a waste treatment facility, the Engineering Department of the industry or industry's Consulting Engineer, should also take part in the survey plan. This will help to eliminate the need for costly repeating of the investigation to supply specific engineering data that the engineer will require.

This is a paper presented before the 2nd Annual Ohio Water Clinic of the Dept. of Civil Engineering of the Ohio State University. The author was formerly Supervisor of Sanitary Engineering Operations for The Ford Motor Co. and a leader in the Michigan Sewage Works and Industrial Wastes Assn. Mr. Cooper's paper has been released by the Program Committee of the Ohio Water Clinic for publication in *Water & Sewage Works*.

Personnel Requirements

Personnel requirements for a survey vary with different industries. Departmental-wise it is rather immaterial who actually makes the study as long as adequately trained persons and suitable equipment are available. In most cases, since the Plant Engineering Department of the industry generally is charged with the correction of any problem that exists, they usually spearhead the survey and arrange the study of the processes, and carry out the actual mechanics of the survey.

The Chemical Engineering, Process Engineering, or a Laboratory, may also carry the major survey responsibility, but in any case, the existing laboratory staff ordinarily is required to carry on the necessary laboratory work. The analytical procedures used in waste analysis, are foreign to the usual industrial laboratory, thus considerable extra work is imposed on the laboratory during a survey of any size.

A liberal "getting-ready period" is generally required for the laboratory to prepare special reagents, glassware, equipment and to locate and test the analytical procedures to be used during the survey.

Making the Survey

The major components of the Industrial Waste Survey are as follows:

A—The plant study
B—Measurement of waste flows
C—Analysis of samples of the waste flow
D—Report of findings

The Plant Study:

The Plant Study is the most important phase of any Industrial Waste Survey and the most neglected in making studies.

It's main purpose is to investigate and report on the disposition of all process chemicals, oils, etc. used in the industrial operation.

It properly begins at the Purchasing Department of the company where a list of *all* the materials purchased should be obtained for the period of a year. With this information the Wastes Engineer should then contact the Stock Department and learn the exact disposition of the materials down to each Department level.

Next in order, is a personal contact with the all important department head or foreman to ascertain exactly how the material is used, and *where it goes.* Often times this is a formidable task, since the foremen and plant personnel often tend to interpret the investigation as one of "checking up" on them and do not cooperate as fully as might be expected, or is essential for the most successful attainment.

This phase of the Waste Survey should determine and record, as carefully as possible, the frequency of releases of all batch discards of process solutions and compounds, who is responsible for authorizing such discards, and most important, the criteria they use in exercising this responsibility.

Here is the place where corrective measures within the plant, to reduce waste losses, usually first become evident. The "reasons for discard" usually lead to methods which can be used to extend the useful life of solutions and in effect reduce waste losses.

At the completion of the process study and after locating and determining the use of all purchased materials, a brief summary of the information should be prepared prior to proceeding with the overall survey.

(a)—To alert the Laboratory on the general character and quantity of materials to be found in the sewer system.

(b)—To differentiate between the "batch" and "continuous" wastes to be expected and to locate on a plant sewer layout the locations where each type of waste flow originates. This in turn simplifies the job of intelligently locating sampling points and those places where flow measurements should be made.

The next step in the plant study should be the measurement of all the individual waste flows from the individual process operations before the waste enters the general sewer system. Samples for laboratory analysis should be taken at the time of taking flow measurements.

At the conclusion of the above Plant Study, the locations of all sources of wastes within the plant and the major information concerning them will have been recorded.

Measurement of Waste Flows

The measurement of total waste flow from an industrial plant requires some knowledge of hydraulics, flow of water in pipes, sewers, channels, use of hydraulic measuring instruments and devices, and last but not least, lots of ingenuity.

It is beyond the scope of this paper to describe the application and use of weirs, current meters, orifices, Venturi tubes, etc. and such measuring methods as salt or chemical dilution, slope methods etc. for measuring waste flows.

Furthermore, there are many excellent sources of information available to assist in properly measuring a waste flow which need not be repeated here. One of the most recent and helpful is entitled "Planning and Making Industrial Waste Surveys" and is published by the Ohio River Valley Water Sanitation Commission[1]. It is an excellent summary of some of the practical methods of measuring waste flows and taking samples.

There are many text books on hydraulics available which describe the more common methods in detail. One text book which is outstanding is entitled "Hydraulic Measurements" by Herbert Addison[2]. It covers in detail most all of the known measurement methods and devices. Another valuable source of information which should not be overlooked are the manufacturers of water and sewage flow measuring equipment. Consulting Civil and Sanitary Engineers can well be called upon for assistance in this activity. They are very familiar with such types of flow measurement.

In completing the total waste survey, measurements of waste flow should be made continuously over a sufficient period of time so that the variations in any average day will be established. This usually involves the installation of a weir or other measuring device (preferably with recorders) at all the sewer outlets from the plant and includes the sanitary sewer as well as the storm and/or the industrial waste sewer. A usual time element used for sampling and flow measurement, is five days starting Sunday night at midnight and finishing Friday night at midnight.

During this period, careful records are kept of the incoming water to the plant by reading the water supply meters on both the city and the plant supply systems. These results provide an overall check on the water being measured at the outlets. It is, of course, desirable, as already indicated, that continuous recordings of the rate of flow at the outlets be made, but if the required instruments are not available, manual readings should be made at not less than 1 hour intervals. It is more important, from the standpoint of waste treatment plant design, to determine the *maximum* rate of flow as well as the total volume discharged. Unless ample holding (waste storage) tanks are to be provided it is the rate of flow which generally sizes any treatment plant, not the total daily volume.

In reducing and tabulating the hydraulic data, it is desirable to do this on a "shift" basis. This provides a means of correlating volume of waste flow with production.

Collection and Analysis of Samples

The proper method of sampling the flow of waste during a survey presents an increasingly difficult problem in proportion to the variety of waste compounds present.

In any waste survey there are a number of different types of samples collected for analysis, however, they generally are the following:

(a) Composite samples collected in direct proportion to the flow, such that at the end of a given period, (say 8 hrs.) the sample theoretically would have the same composition as if it were taken from a thoroughly mixed tank which contained all the flow during that period.

(b) Individual samples taken at 30 min. or hourly intervals during the 8 hrs. and placed in separate bottles for analysis.

Composite samples, following analysis, provide information as to the *average concentration* of different constituents during the compositing period. Together with the flow data collected at the same time, they indicate the total loss of material from the plant during the period tested.

Individual samples are used to indicate peaks in the concentration of various constituents. To show how high the particular waste concentration gets during the composite period. These individual samples are necessary when there are quite wide variations in waste discard. Planners of a survey should constantly be reminded in establishing their sampling program, that "concentration is the criteria of destruction," not total pounds or tons or other similar yardsticks and it requires individual samples to properly evaluate peaks in concentrations of wastes. For example when discards of both acids and alkalis occur during the composite period, individual samples are required to show the variations in pH, acidity, and alkalinity.

Another use of the individual samples occurs when some type of "fixation" is required, such as the addition of copper to fix samples for phenol determinations. If a fixative is added to the composite very often it will cause an interference with some other required determination.

Composite samples greatly lessen the work load on the laboratory, thus are preferred to individual samples and actually are too often used without sufficient supplementary individual sampling. There are a number of mechanical devices available which, especially in the case of smaller flows of waste, can continuously collect a composite sample in proportion of the flow. An excellent description of some of these devices is included in the publication mentioned above "Planning and Conducting an Industrial Waste Survey"[1].

Besides the automatic composite samplers there is need for a variety of individual sampling devices. We have found that usually about four of these units will serve in most conditions. They are:

(1)—A sampler to hold and fill dissolved oxygen sample bottles. This is a special, but necessary device for collecting samples for measurement of Biochemical Oxygen Demand (B.O.D.) and Dissolved Oxygen (D.O.)

(2)—A sampler to collect a portion of water or waste flow at some predetermined depth.
(For such we have very successfully used the LeForest Sampler, known to Zoologists as a "Juday" bottle.)

(3)—An oil sampler which operates like a "cookie cutter" and collects a sample of water with oil on the surface such that the oil concentration can be expressed in p.p.m. of the waste flow.

(4)—The "old faithful" a 10 qt. pail with a rope.

Laboratory Program

The proper procedure in testing samples submitted to the Laboratory requires considerable pre-survey study and preparation.

Most industrial plant laboratories have to first purchase the type of glassware needed and prepare the special reagents used in waste analysis. Precision in making determinations which measure wastes to fractions of parts per million are not common in industrial control laboratories and many industries have felt it necessary to establish a separate water and Wastes Laboratory specifically for carrying out the analysis required in sanitary chemistry and later for waste disposal control.

Before making a survey the Laboratory should assist in establishing the proper sampling points. The specific tests to be made on each sample from each sampling point should be decided in advance and a laboratory test schedule should be prepared to indicate to all technicians what to do with each sample. The schedule should also establish the priority of the various tests to be made on a given sample as there may be a decomposition of some particular waste constituent which would require it to be determined immediately. The schedule also indicates those tests which may be deferred until the press of the survey is over.

Next is a determination, in advance, of the number of samples to be collected and their volume. This necessarily has to be tailored to the personnel and equipment available, but in general the greater the number of samples, the more accurate the survey.

Another factor, often overlooked but very important, is the matter of transportation of the samples to the Laboratory. Often when a number of operations or outlets are being sampled at the same time, it is a formidable task to get all the samples to the laboratory steadily, over say, a five day period.

I recall in a few surveys when the sampling points were quite a distance apart and there was a rapid deterioration of the organic material being investigated, we set up a 24 hour schedule broken down to the exact time in minutes when the Waste Engineer was to appear at each sampling point and what samples were to be taken at each stop. The engineer then made a trip in a car to all points checking time required to be certain that the rigid schedule could be kept.

Prior to actually making analysis on waste samples quantitative exploratory checks on typical grab samples should be made to insure that no possible unknown interfering constituent might be present in the samples. A number of these quick exploratory tests are published in a booklet "The Determination of Water Quality" Research Report 9, U.S. Fish and Wildlife Service, Washington, D.C.—procurable for 25 cents.

Before the survey gets underway quantitative tests should also be made on the wastes to polish up the technique required and establish the amount of time required to make the test. This is particularly important in case of testing for toxic metals, phenols, biochemical and chemical oxygen demand etc.

The proper choice of which of the various analytical procedures available to use is often difficult and it is strongly urged that the chemist-in-charge contact the local, state or Federal pollution control agency for assistance in making his choice. The local water or sewage treatment plant chemist often can give valuable assistance to the industrial chemist.

"Standard Methods for the Examination of Water and Sewage" are official for sanitary chemists and should be followed whenever possible. It is produced by the Federation of Sewage & Industrial Wastes Assns., the Am. Water Works Assn. and the American Public Health Assoc. It is published by the latter but may be purchased through either of the three. Another very practical text is the "Analysis of Water & Sewage" by Theroux, Eldridge & Mallman and is available from the McGraw-Hill Book Co.

Many of the special tests and analytical procedures required in waste analysis still are widely scattered in the literature and it is suggested that the various technical journals, and trade publications, for example "Sewage and Industrial Wastes," "Water and Sewage Works," "Wastes Engineering" "Industrial and Engineering Chemistry," (Analytical Edition) and others be reviewed to locate the most applicable test procedures. The U.S. Public Health Service, Cincinnati, Ohio, can provide valuable technical advice and laboratory procedures as can chemists associated with the various state and regional pollution control agencies.

One other phase of the laboratory program which should not be overlooked, is to establish proper preservation of samples between the time collected and the laboratory analysis. The above mentioned sources of technical information include methods for preservation of samples.

The Report of Findings

To this writer the final report of the survey always seemed to be the most difficult part of the study. It should, of course, encompass all phases of the study in the plant, the hydraulic data, results of the survey and include an explanation of the analytical data.

It is a compilation of facts, together with all supporting data which substantiate the facts presented, and comprises the permanent record of the work.

Whether or not an interpretation of the facts should be included in the report will vary with the training and experience of the report writer and his ability to evaluate the results and their overall effects on receiving waters. Very often this phase of the report should be prepared by an expert consultant who, by wide experience and training, can authoritatively interpret the findings so that the future course of action by Plant Man-

agement is readily apparent and understandable.

If an interpretation of the survey is to be included in the report, the following are a few suggestions to consider:

(a)—Determine if objectionable pollution exists. Consider *concentration* of wastes rather than pounds, tons, etc.

(b)—Compare findings with Stream Standards, Guides, or Public Sewer Use Regulations.

(c)—Calculate from results of studies the quantities of wastes to production units.

(d)—Make a careful search of literature before accepting or suggesting any lethal limits of wastes in receiving water. (There is a wide variation of opinion on what should be considered *"too much"*)

(e)—Do not use the term "population equivalents" on Industrial Wastes *unless* a curve has been established to define what percent of the B.O.D. of an industrial waste is indicated by the Standard Methods 5-day B.O.D. determination

In many cases completion of the survey by industrial plants has merely confirmed that a possible suspected problem turns out to be no problem at all. In the case of a greater number of industries, however, completion of the survey is merely the first step in their program of co-operation with the public and pollution control agencies in the ever increasing national movement looking to better industrial wastes control and betterment of stream conditions.

References

(1) Ohio River Valley Sanitation Commission, 414 Walnut St., Cincinnati 2, Ohio.

(2) "Hydraulic Measurements" H. Addison. John Wiley & Son, New York, N. Y.

A Correction

Proving that W. & S. W. is Well Read.

In our March issue a news item, captioned "Jim Brower Retires," credited Mr. Brower and the late Darwin Townsend as co-inventors of the "Tow-Bro" Clarifier Mechanism. It was stated that Mr. Townsend was at the time superintendent of the Milwaukee Activated Sludge Plant.

John W. Townsend of Chicago, son of the late Darwin Townsend, has pointed out to us that the latter statement should be corrected, since his father was at no time plant superintendent. During his 20 year connection with the Milwaukee Sewerage Commission (1914-1934) Mr. Townsend advanced from Chief Draftsman to Acting Chief Engineer, from which position he resigned to enter the consulting field as a partner in the firm of Consoer, Townsend & Quinlan of Chicago—now Consoer, Townsend & Associates.

Worth Cogitating . . .

"The day of the rugged individualist is gone . . . The management of business has left the hands of its owners and come into the hands of the professional manager, an employe himself . . . Perhaps the strangest thing about the professional manager as we know him today is that he is not working primarily to get rich . . . He is primarily driven by three things. The most obvious, of course, is the desire to do a good job and to be recognized for it. Second, and more important . . . few men rise through the ranks of modern business organizations unless they are unusually adept at helping the men they work for, the men alongside them, and the men who work for them . . . The third driving force is simply self-preservation. Unless he can provide a reasonable return . . . he will not long remain a manager."

. . . . *Jervis J. Babb, president of Lever Bros. Co. to the New York Economic Club.*

Bayonne Chamber of Commerce Sets Unusual Example of Public Service

The $30,000 investment made by the Bayonne Chamber of Commerce to keep watch while the city builds an expensive sewage disposal plant is already demonstrating its value. The plant will cost so much money that before the city started work it had to secure legislation to increase its bonded debt limit.

With this cost figured at $10,000,000, the Chamber of Commerce members decided that it would render an unusual and valuable public service by putting up a $30,000 fund to hire engineers to advise the Chamber as the work progressed. On top of this there is a suit in court in which exception is taken to certain actions by the city's engineers.

The Chamber's engineers have made their first report. It shows that several suggestions made to the city's engineers were so well thought of that they were adopted without recourse to the City Commission for permission. That is paying off in a practical way.

City officials are used to getting a lot of free advice, but they'll agree that it is distinctly unusual for anybody to pay out good money for the advice they give gratis. The sewage disposal project has progressed to the stage where the matter of financing its operation is now under consideration.

The decision on this question will depend materially on whether a paying market can be found for the fertilizer that the plant will produce. In this, the Bayonne plant may have to compete with the various other similar plants to be erected in this area.

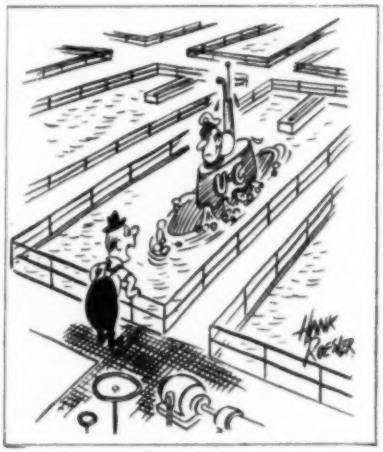
In any event, the cost must be met by taxation or otherwise. The plants are being constructed under a court order from which there is no escape because the health of the community is involved.

Laboratory Technique Ideas from Capitol's Water Plant

Staff members at the Dalecarlia water filtration plant, Washington, D.C., some months ago developed two techniques which save considerable time and expense in processing the fermentation tubes used in bacteriological analyses of water samples.

In place of the sterile cotton plug ordinarily used as a test tube cap, it was found that the unthreaded type of aluminum cartridge case usually provided for 35-mm. camera film could be used. These discarded aluminum cases are available in quantity at photographic shops. They offer the following advantages over the cotton plug: Slightly chipped test tubes can be safely used with these caps; faster manual handling is possible; and the aluminum caps can be sterilized and reused.

In the second technique, a special, large, mechanical washing unit was obtained which allowed assembled fermentation tubes and gas tubes to be cleansed effectively without separating them. This eliminates several time-consuming hand operations.



"Naw, this ain't no Navy Yard! Hits the City Sewage Treatment Plant!"

N. J. Sewage and Industrial Wastes Assn. Holds Record Convention

38-Year-Old Organization Meets March 11-13 in Atlantic City, N.J.

President
Sol Seid
Supt. Public Wks.
New Brunswick, N.J.

1st Vice Pres.
John W. Hood
Supt. Treatment Wks.
Ridgewood, N.J.

EVIDENCE that an interesting program of timely subjects will invariably draw a large attendance at meetings was again thoroughly demonstrated at the Atlantic City meeting of the 38-year-old New Jersey Sewage and Industrial Wastes Association on March 11th through 13th.

The registered attendance proved to be a record 436. Also this meeting was the best attended by the women folk for which entertainment was planned for the first time in this venerable Association's history. The annual "Speechless Dinner" conceived many years ago by P. N. Daniels (the local committee) was again a big success. These dinners are now financed by The Water & Sewage Works Mfgrs. Association from funds derived from exhibitor fees. This year there were 19 firms represented in the exhibit area.

This being an off year for elections, which are held each second year, the officers remain the same as last year.

President—Sol Seid, New Brunswick, N.J.

1st. Vice Pres.—John Hood, Ridgewood, N.J.

2nd. Vice Pres.—John Collum, Bordentown, N.J.

Secy.-Treas.—M. S. Kachorsky, Manville, N.J.

Nat'l Director—Henry Van Der Vliet, Rutherford, N.J.

Daniels Honored

P. N. DANIELS, Sanitary Engineer for Trenton, N.J., former asst. chief engineer of the N. J. Dept. of Health and the only living charter member of the Association was voted the Arthur S. Bedell Memorial Award "for outstanding services to the Association over a period of many years." "P. N." has long been a real wheel-horse in the Association and a continuing member of its Executive Committee for about as long as even the oldest members can recall.

Technical Sessions

The meeting opened with a movie presented by "Bill" Gross, District Manager for Infilco, Inc. of Tucson, Ariz. The movie pictured among other things the Daytona Beach Process of sewage treatment, invoking the use of softening plant sludge and a minor application of air to maintain aerobic conditions in the "Accelator" sludge blanket type clarifiers.

JOHN R. SPERRY of Walker Process Equipment, Inc., Aurora, Ill.

Honored "Wheel-Horse"
P. N. Daniels
City Sanitary Engr.
Trenton, N.J.
(The Bedell Award and Appreciation)

gave an illustrated description of "THE WALKER IMPINGEMENT AERATION SYSTEM" which requires no air cleaning equipment, since the air enters through jet nozzles and strikes an inverted saucer which emulsifies the jetted air. He explained the economy of the impingement method of aeration for activated sludge and recarbonation of softened water. Readers interested in this newest of methods of activated sludge aeration and diffusion of carbon dioxide are referred to the article on "Impingement Aeration" by Joe Kruegel, Sup't. Sewage Disposal at Kirkwood, Mo. pp. 176-179, *Water & Sewage Works, April, 1953, issue.*

A Sewage Plant of Parts

WILLIAM HIGGINS, young and upcoming Superintendent of the Gloucester, N.J. Sewerage Authority, in an excellently prepared paper described "THE NEW SEWAGE TREATMENT PLANT OF GLOUCESTER, N.J." of 4.5 mgd. capacity for a community of but 16,000 which voted a $1,300,000 bond issue for the purpose. Andrews and Gieseki Engrs. designed the combination sewage treatment and incinerator plant.

2nd Vice Pres.
Jack W. Collom
Supt. Sewage Wks.
Bordentown, N.J.

Secy.-Treas.
M. S. Kachorsky
Supt. Public Wks.
Manville, N.J.

Sewage from four district lift stations, equipped with automatic Chicago Flush-Kleen Pumps, deliver to the main pumping station from which it is pumped to the treatment plant by Am. Well Works Pumps. The main pumping station is also equipped with Link-Belt Grit Washers and Chicago Pump Co. Comminutors.

At the treatment plant the flow is recorded by a Simplex Venturi Meter and distributed to four primary settling tanks equipped with Chain Belt Straight Line Sludge and Scum Collectors. Settled sewage passes through two Dorrco Bio-Filters with re-circulation provided by Fairbanks-Morse Pumps, which deliver filter effluent to the influent end of the primary tanks in ratio of 1.5 returns to 1 of sewage flow. The filter effluent not recirculated passes through final tanks of same general design and sludge removal equipment as the primary tanks, except that the first tanks have H type effluent take-off launders (weirs) that serve admirably in that the light fluffy sludge from the Biofilters is not lifted by outflow currents. At the end of the plant is the chlorine mixing and contact chamber fed chlorine from a Builders-Providence Chlorinator. The plant is designed and equipped for pre-chlorination also when desired.

At present the average sewage flow (combined sewers) is 2.25 mgd. An

Programmers

John R. Sperry
Sanitary Engr.
Walker Proc. Equip.
Aurora, Ill.

W. W. Eckenfelder
Weston Eckenfelder
& Hood
Ridgewood, N.J.

Wm. Higgins
Supt.
Sewerage Authority
Gloucester, N.J.

Paul J. Cerny
Sales Engr.
The Dorr Co.
Stamford, Conn.

overall average B.O.D. reduction of 75% and suspended solids removal of 85% is being obtained consistently.

Practice has shown that sludge withdrawal once daily from the primary tanks is preferable to more frequent withdrawals. The sludge is first decanted and then pumped to the primary digester equipped with a P.F.T. Floating Cover and recirculation pumps. The sludge pumps are Carter Duplex Displacement Pumps. Sludge pre-heating is effected by heating supernatant liquor (recirculation effect) which is added to the cold primary sludge during sludge pumping to the digesters. This scheme has proven superior to that of passing sludge proper through the P.F.T Heat Exchangers. In addition to pre-heating of sludge the P.F.T. Exchangers operate automatically to recirculate and heat the digester contents to maintain digester temperatures in the optimum range. Heating and recirculation repeats every 6 hours automatically and shuts down by thermostatic control tied in with internal digester temperature. Sludge is transferred from the primary to secondary digester only at three week intervals. A novel expedient is that of sludge washing (elutriation) between the two stages of digestion. This unusual procedure results in a greater density of the final sludge drawn from the second stage digester. The sludge wash water (600 to 700 ppm suspended solids) is delivered to the plant inlet. The digester design is liberal—namely, 4 cu. ft. per capita; so little trouble has been experienced.

Both digesters are equipped with Supernatant Selectors. In the early stages (3500 ppm suspended solids in supernatant) the selector screens in the primary digester clogged. Removing and cleaning these useful adjuncts presented no great problem. Supernatant from the secondary digester (400 to 500 ppm suspended solids) has been no problem and is delivered to the plant inlet.

Sludge from No. 1 digester runs 9% solids and 62% ash while that from No. 2 digester runs 14% solids and 73% ash. Be it recalled that the latter represents sludge which has been washed in the course of transfer from the primary to secondary digester. Marlow Pumps deliver final plant effluent to the twin sludge elutriating tanks which are equipped with straight-line sludge collectors.

Secondary sludge is again washed and delivered to concentrating tanks from which it is delivered by Link-Belt Bucket Elevators to conditioning tanks where ferric chloride coagulant is added by Proportioneer Chemical Feed Pumps. The conditioned sludge is dewatered on two Komline-Sanderson Sludge Filters of the drum-type, which feature life-time stainless steel springs as the filtering media and radial filtrate piping external to the drum for easy access if cleaning should be required. The filter cake, averaging 72% moisture content is readily dried and burned in the 60 ton Morse Boulger Automatic Stoked Incinerator of rotating hearth design. The wet cake is dried sufficiently in 8 to 10 minutes on the rotating hearth to burn when dropped from the hearth. The rate of drying is 1500 lbs. of wet filter cake (72% moisture) per hour. The incinerator has required no auxiliary fuel beyond the trash and rubbish of the community. However an oil burner is available if needed under adverse conditions.

Biggest headache in plant operation and maintenance have been the submerged pumps in the sump pit receiving all liquid wastes from the various operations. From the sump the submerged automatic pumps deliver to the head of the plant.

Another headache said Supt. Higgins (and an expensive one) had been packing replacement on the duplex plunger type sludge pumps every 4 to 6 weeks, at $45.00 for the packing alone. In an article on packing troubles they had read of the use of ordinary 5/8" garden hose instead of the expensive "store-bought" 3/4" packings. This did it!! After 12 weeks of operation neither pump has shown any leakage around the 5/8" garden hose packings. Mr. Higgins cautioned not to tighten down on the hose ring too much. Said he, let it leak a bit at first; it will gradually stop. Actually the packing gland might better be loosened a bit after a day or two of swelling of the hose ring. In brief, it is better to run with the packing seeping than to have it under too much compression.

[Ed. Note: Mr. Higgins has agreed to give *W. & S. W.* an article more exactly describing how best to fit and maintain the economical long service 5/8" hose packing; and, also to relate other "kinks" and the like which he and his operating staff have put to effective use at the Gloucester Treatment Plant and Pumping Stations. Watch for "helpful hints" in a future issue.]

Bio-precipitation of Canning Wastes

WESLEY ECKENFELDER of Weston, Eckenfelder & Hood, Inc., Ridgewood, N.J., presented some data on the effectiveness of controlled "BIO-PRECIPITATION OF FOOD PROCESSING WASTES" as applied in a new treatment plant of the H. J. Heinz Co. at Chambersburg, Pa., built and equipped at a capital cost 50% of that of a conventional biological treatment plant to handle the same loadings and operating at a cost of $15 per 1000 lbs. of C.O.D. (chemical oxygen demand) removed. The process requires the services of a single operator only because so much of the operation is on an automatic control basis. The secret of even operation and dependability of the process hinges on the automatic control of air input to maintain an oxygen balance without waste, the use of ammonia to maintain a balanced food supply for organisms, and pH values in optimum range of 6.0 to 8.5 by automatic alkali additions. Employing an Infilco Aero-Cyclator and sludge recirculation in 1:1 ratio with solids removal by aero-flotation and vacuum filter dewatering, the B.O.D. removal had been maintained between

National "Brass"

L. J. Fontenelli
Supt.-Engr.
Sewerage Authority
Rahway, N.J.
(Federation Vice-Pres.)

Henry Van der Vleit
Supt. Treatment Wks.
Rutherford Jt. Meeting
Rutherford, N.J.
(National Director)

85 and 90% (430 B.O.D. reduced to 72 B.O.D.) on flow of 0.55 mgd. with 60 lbs. of ammonia and 30 lbs. of caustic soda per day.

The Vacuator Does a Job

PAUL J. CERNY, Sanitary Engineer of The Dorr Co., described the basic features of "THE DORRCO VACUATOR" which performs a rapid pretreatment of wastes and sewages, involving injection of minor quantities of air (0.05 cf./gal.) under pressure, followed by a sudden creation of partial vacuum (9 in. of mercury) which produces aero-flotation of solids, greases, etc.

Speaking of some of the 42 installations of the Dorrco Vacuator since its introduction in 1941, Mr. Cerny cited a California plant coping with fruit canning wastes in which the Vacuator was accomplishing more than primary settling units ahead of

Committee Chairmen

Harry Greenfield
San. Engr.
State Dept. Health
Trenton, N.J.
(Arrangements)

Andrew Palmer
Supt.
Plainfield Jt. Meeting
Dunellen, N.J.
(Publicity)

Bio-filters during the canning season. In 10 minutes through the Vacuator 41% suspended solids removal resulted. With wholly sewage the removal reached 49%. Other Vacuators had reduced B.O.D. by 30 to 40% and suspended solids removal of 40%. In another case of domestic sewage the Vacuator alone with 16 minutes of detention, had given higher reductions of suspended solids than had a primary clarifier alone with 120 minute detention.

Treatment for Anti-biotic Wastes

FRED E. REIMERS, Chemical Engineer with Merck & Co., Rahway, N.J., presented findings in the "STUDY OF TRICKLING FILTERS FOR TREATMENT OF FINE CHEMICAL WASTES" at the Front Royal, Va., plant of Merck & Co. These studies on pilot plant scale supplied data for the design of the full scale plant with 4 ft. depth primary and secondary trickling filters. The unexplained observation was that filters of 4 ft. bed depth had performed better than the 6 ft. depth pilot plant filters. The dilution rate was to be 5 to 1 and filter loadings of 1.9 to 2.0 lbs. B.O.D. per cu. yd. per day.

Programmers

*Chas. H. Capen**
Chief Engr.
No. Jersey Water Comm.
Wanague, N.J.

Richd. E. Bonyun
Ch. Engr. & Supt.
Passaic Valley W. Comm.
Clifton, N.J.

Fred E. Reimers
Chem. Engr.
Merck & Co.
Rahway, N.J.

Edw. P. Molitor
Supt. Jt. Meeting
Madison-Chatham
Chatham, N.J.

*(*President of the Am. Water Wks. Assn. Also in this issue read the "Guest Editorial" by Mr. Capen on the meaning of cooperation.)*

Study of disposal of the sludge had shown the practicability of land disposal at rates up to 0.05 gals. per sq. ft. of disposal area. Such rates can be applied in winter as well as in summer, therefore land disposal had been chosen as the most economical and practical disposal of the 12,000 gpd. of sludge. The final plant effluent is distributed across the flow of the Shenandoah River through a submerged header drilled for the purpose.

Modernization of State's Oldest Plant

E. P. MOLITOR, Supt., Madison-Chatham Joint Meeting, described "IMPROVEMENTS TO THE MADISON-CHATHAM SEWAGE SYSTEM" which have been completed recently. In addition to construction of a 6,000 ft. trunk sewer, the existing Imhoff tanks (earliest in America) were converted to settling tanks and facilities for the activated sludge process were provided. A contact chamber and chlorination facilities have been included in the newly modernized plant, with provisions made to chlorinate all bypassed storm flows. Frothing is controlled by the use of an anti-foam compound. Final clarifier effluent averages 6 to 10 ppm suspended solids with an overall plant reduction in B.O.D. of 95 per cent.

External heating is provided for two-stage sludge digestion, which was initiated without seed and a minimum of lime.

Colored motion pictures provided exterior views of the plant, while slides were used to illustrate the color-coded piping systems and other interior portions of the plant.

Design features of the new trunk sewer and recirculation features built into the plant to prevent shock load interference in the activated sludge process were discussed by E. T. KILLAM, Consulting Sanitary Engineer, Short Hills, N.J.

H. M. WEIL, Sales Engineer, Chain Belt Co., New York, N.Y., presented a discussion "REX TOW-BRO ACTIVATED SLUDGE TREATMENT PLANTS." The apparatus described enables activated sludge collection with a minimum of disturbance. The equipment may be installed in rectangular as well as circular sedimentation tanks.

Slides illustrated the features of complete sludge removal, high density sludge withdrawal and B.O.D. reductions at Sioux Falls, S.D., before and after installation of Tow Bro equipment.

Capen Pleads Cooperative Efforts

CHAS. H. CAPEN, Pres., A.W.W.A., and Chief Engr. North Jersey District Water Supply Commission, in discussing "WATER WORKS IMPROVEMENTS AND INTEREST IN STREAM POLLUTION," emphasized the public awareness of clarity and good taste in its water supply. Good appearance of streams and food fish areas are becoming increasingly important for favorable public relations.

Intensive use of surface waters causes changes in water shed usage, making the utmost cooperation between water and sewage works men necessary to get good results from pollution abatement programs.

R. E. BONYUN, Chief Engr., and Supt., Passaic Valley Water Commission, continued the discussion begun by Mr. Capen, referring to pollution problems as they effect the water plant operator. He pointed out that the rights and privileges of others must be recognized in watershed management.

Increases in population and industrial plants have occurred along the Passaic River, entailing the acceptance of a certain amount of pollution load

in the watershed. The plant operator, in order to cope with problems resulting from watershed changes has resorted to pre and post-chlorination, activated carbon, use of coagulants, settling basins and ammoniation. Legal rights should be enforced only as a last resort.

Replying to a question asked by Mr. Enslow, Editor, *Water & Sewage Works*, Mr. Bonyun stated that watershed rights have been protected in New Jersey since 1899. The act has been amended when necessary, but is enforced by the State Board of Health on the request of the water purveyor.

H. E. Orford, Acting Chairman, Dept. of Sanitation, Rutgers University, New Brunswick, N.J., reviewed "Sewage Treatment of New Jersey State Institutions." A population of 24,500 plus employees discharges wastes of which 30 per cent are sewered to municipal plants and 70 per cent are subjected to all types of sewage treatment processes.

The State Department of Agencies and Institutions is presently engaged in a major improvement program, the first in twenty years. "Progressive in thought, but conservative in design" is the general attitude of the department as they meet problems of design which differ from ordinary domestic wastes. Designers are presented with higher than average flows (158 gal/cap/day) and stronger sewage in terms of B.O.D. (0.30 lbs. cap) per day. Design is based on a 25 hour day of 200 gal/cap, 0.34 lbs/BOD/cap, and 0.30 lbs. of suspended solids/cap. Licensed operators are employed to operate all plants and other measures are observed to cooperate fully with the State Health Department.

NJS & IWA Proud of "Veep" Fontenelli

L. J. Fontenelli, Supervising Engineer, Rahway Valley Sewerage Authority, Rahway, N.J., spoke in his capacity as Vice President of the Federation of Sewage and Industrial Wastes Association. He reviewed the objectives of the Federation, emphasizing that in its twenty-fifth year, the goal is 6,000 members. Present membership is 5,500 indicating a seven per cent increase for each association, as its share in the program.

The Journal of the Federation, together with the several "Manuals of Practice" which have been issued, seem to promulgate valuable information. Technical committees guide and stimulate research work, while the annual meetings of the Federation allow a free exchange of information. The 1955 Annual Conference of the Federation will be held at the Ambassador Hotel, Atlantic City, N.J.

That fellow members of N.J.S. & I.W.A. were proud of their past-president and future president of the entire Federation was clearly demonstrated by the "big-hand" that Lou Fontenelli received and rightly deserves.

Chlorine Determination

R. V. Day, Research Chemist, Wallace and Tiernan Co., Bellville, N.J., described "New Developments in Chlorine Determination" as recommended for inclusion in the Tenth Edition of Standard Methods for the Examination of Water, Sewage and Industrial Wastes.

A research project was organized to investigate known methods for determining residual chlorine. The ortho-tolidine, starch-iodide and amperometric procedures are being recommended, because the committee is agreed that each has its place. The magnitude of the value obtained differs with the analytical method employed: starch iodide and the amperometric results agree fairly well, while results using ortho-tolidine are, in general, much lower than the other two methods, of the order of magnitude of 2.5 ppm less in primary sewage treatment plants. Organic matter reduces the precision of all methods.

It is proposed to eliminate the present chlorine demand test in favor of a new procedure termed "chlorine requirement," which relates the amount of chlorine required to produce a chlorine residual after a definite contact time and provide an effluent of the desired coliform density.

Dr. H. Heukelekian, Research Engr., Rutgers Univ., New Brunswick, N.J., discussed the paper presented by Mr. Day. He pointed out the objective of sewage chlorination is disinfection to remove pathogenic organisms, and that a simple, accurate, consistent test is required to control the process.

Flocculation

J. J. Horgen, Sales Mgr., R. B. Carter Sales Inc., Hackensack, N.J., used an operating model to describe the "New Walking Beam Type Floccer." Features of the coagulation equipment include location of lower units above the liquid tank level and ready access to connecting rods and walking beams which operate the mixing devices. The equipment is applicable to industrial waste treatment by substitution of stainless steel and silicon bronze fittings where required.

E. A. Bell, Borough Engr., Essex Fells, N.J., affirmed that "the first fifteen years are the hardest in 'Operating a Chemical Coagulation Sewage Treatment Plant,'" as he described, oftentimes humorously, his experiences from the operation of a 200,000 gal/day plant. Air agitation is used to mix and flocculate the sewage after the addition of ground aluminum sulfate. Returned supernatant liquor is chlorinated, as is the effluent from sand filters, which have required new sand only once in fifteen years. Mr. Bell described how inaccuracies in flow measurement were corrected by lining the Parshall flume with aluminum and how a bulldozed lagoon enabled repairs to be made when a ruptured heating coil vent filled a digester.

John J. Horgan
Sales Manager
R. B. Carter Sales Co.
Hackensack, N.J.

Programmers
H. Heukelekian
Research Engr.
Rutgers Univ.
New Brunswick, N.J.

E. Arthur Bell
Engr.-Supt.
Water & Sewage Wks.
Essex Fells, N.J.

Sewage Treatment Costs and How Met

Sol Seid, Association president, introduced a three member panel to discuss "Comparison of Sewage Treatment Costs by Sewer Rentals—Sewerage Authorities and Direct Taxation."

W. S. Foster, Engineering Editor, *The American City*, provided an excellent insight into the complexities and inconsistencies of sewage system financing. He listed numerous communities, large and small, indicating methods used to raise funds, including flat rate charges and charges based on percent of water bills. It was

pointed out that thoughtful consideration and diplomacy are required when establishing the rates to be charged industry. Several cities were cited as not having hesitated to charge a comparatively high rate, apparently successfully. Mr. Foster concluded that if a decision is made to adopt sewer service charges, those concerned with sewage works should "keep in mind that such a charge offers the opportunity to see that all portions of the sewage works are properly financed, including the salary of the superintendent and his associates."

A. D. Cross, Jr., Secy., Sewerage Authority, Mount Holly, N.J., was the second panelist. He related some of the advantages of the recently legalized Sewerage Authority in New Jersey, which can be financed and operated independently of the municipal government. In fact, under New Jersey law of 1946 Water and/or Sewerage Authorities are classified as political subdivisions which have the authority to issue bonds and set rates for utility service without obtaining approval of the State Utilities Comm. Speaking from experience as Secy.-Manager of the second oldest Sewerage Authority in the State, Mr. Cross said that the number one consideration was the employment of a qualified engineer to prepare plans, cost estimates and develop an adequate rate for sewer service charges to cover all costs and have something over for building a modest surplus. With confidence in the engineer and the proposed rate structure, sale of revenue type bonds at a low interest charge would be no problem.

Best by far was the charge based on metered water use with the charge added to the water bill as a separate item. Where a flat rate proves necessary, he advocated charging on the basis of number of persons residing in or occupying the property served in preference to the less equitable rate based on number of fixtures on the premise.

In revenue bond financing experience and expert guidance in an all important consideration since the bond resolution should be made as flexible as permissive. The existence of a lien law making unpaid service charges a tax lien against the property made for bond marketing at the most favorable rates of interest comparable with the safest municipal bonds. Bonds should be subject to retirement serially from surplus earnings as rapidly as desired.

As to billing and collection of service charges he favored quantity billing along with water service billing as sufficient and more economical than monthly billing. Interestingly, Mr. Cross is manager of the local Mt. Holly Water Co. and was drafted for his job as manager for the Mt. Holly Sewerage Authority. As fate would have it, the new sewer service charge based on water meter readings had been responsible for local conservation in water use and a 15% reduction in gross income to his company. Questioning disclosed that the 15% loss in gross had persisted. However, said Mr. Cross, the Sewerage Authority had been satisfactory to Mt. Holly and the 5 man Board of rotating membership which had operated the facility on a business like basis soundly financed and managed.

W. S. Coward, Asst. Chief Auditor, Division of Local Government, State of New Jersey, Trenton, N.J., final panel member, discussed the three basic methods by which sewer systems may be financed in New Jersey. A sewerage system may be constructed and operated by general taxation, the necessary funds being derived from the municipal budget. A municipal utility may be created which can levy annual charges to defray construction and operation costs. The final method is of recent origin and is based on the Sewerage Authority Law enacted in 1946.

Several combinations of the basic methods are commonly used to supply funds, with assessment against the properties benefited usually included to cover costs of the trunk services and laterals.

Harold M. Weil
Distr. Sales Engr.
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Programmers
H. E. Orford
Actg. Chmn.
Dept. of Sanitation
Rutgers Univ.

J. C. Albertson
Partner
Bowe & Albertson
Engrs.
New York, N.Y.

Operators' Breakfast and Symposium

A Symposium titled "Municipal Treatment Plant Problems with Industrial Wastes" was a feature of the operators' breakfast. Louis J. Fontenelli served as moderator and introduced P. N. Daniels who presented the operators' viewpoint in connection with handling industrial wastes at the sewage treatment plant. He pointed out that the operator is the "middleman" and should obtain all available facts about the waste to be added, prepare himself in advance as to what might happen to the plant operation and then report to the responsible control body.

J. C. Albertson, Consulting Engr., Bowe, Albertson and Associates, New York, N.Y., discussed the topic as viewed by the consultant. He favors the inclusion of industrial wastes with sewage wherever practicable, but said such factors as toxicity of the wastes must be controlled and industry should pay its share of costs. The Health Department should serve as liaison representative between the principals concerned in the problem of combination treatment of sewage and industrial wastes.

The attitude of the State Health Department was stated by L. A. Greenberg, Public Health Engr., as favoring combination treatment of domestic and industrial wastes. It may be necessary for industry to pretreat particular wastes that might interfere with normal treatment procedures.

Dr. C. K. Banks, Vice-Pres. and Director of Research and Development, The Metal and Thermit Co., New York, N.Y., speaking from the point of view of "Industry," commented that progressive management must appreciate the need for waste abatement. A strong desire of industry is to curtail pollution by conserving process ingredients where possible. Should problems arise in connection with waste disposal through the municipal sewer system, thorough understanding of the problem and what must be done about it are necessary to secure industry's full cooperation.

The Symposium was concluded by Mr. Fontenelli, who pointed out that industrial and population growth proceed simultaneously and, in the case of the Rahway Valley Sewerage Authority industrial wastes will be accepted with the minimum of pretreatment required to protect the sewers and treatment facilities.

Electric Controller Maintenance

A Summary of Recommended Preventive Measures Designed to Protect Personnel and Equipment

by L. E. MARKLE, *Manager, Control Equipment Engineering*
Westinghouse Electric Corp., Buffalo, N.Y.

MAINTAINING your electric motor controllers prevents expensive repairs and costly "downtime" of equipment. For good maintenance, these considerations are important:

1. The first and most important requisite of good maintenance is safety to personnel. Safety is accomplished by enclosing, guarding, or remotely locating apparatus to avoid personal contact—and by disconnecting all power before touching or repairing any apparatus.

2. The initial installation should be well made. All parts should have ample capacity. Installation work and wiring connections should be well done. Tests should be made to prove the adequacy of the equipment and installation before final acceptance is granted by ultimate user.

3. An adequate supply of correct renewal parts should be available for prompt use when replacements are necessary. Renewal parts should be obtained from the manufacturer of the original equipment, to be sure that the parts are correctly made.

4. A systematic and regular plan of inspection should be arranged to keep all equipment in good operating condition. Such a plan provides preventive maintenance.

Preventive Maintenance

Some suggestions for good preventive maintenance are:

1. Personnel should be capable and alert, trained and prepared to make repairs when the need is first observed.

2. Regular inspections of equipment should be made, frequently enough to prevent serious trouble from developing.

3. If extensive repairs are required, inspector should report them immediately — initiating plans for the work as soon as possible.

4. Records indicate which installations are most troublesome, what repairs most frequently needed. They minimize interruption of service when a major maintenance job must be done. And, records show whether or not maintenance costs are excessive.

Any record that keeps the desired maintenance information in good order is satisfactory. It should be a convenient record, easily maintained. Maintenance personnel soon will know what type of record best suits their needs.

A suggested record form is shown in Fig. 1. Since controllers and motors are closely associated, this record includes information on both.

Controller Enclosures

Most controllers are mounted in some kind of metal enclosure. This may be done to protect personnel from live parts, or it may be desirable because of local conditions. The most common enclosure is a sheet metal one that enclosures all live parts. It may be ventilated or non-ventilated.

For cement dust, coal dust, and locations where dirty atmospheric conditions exist, dust-tight enclosures will reduce the maintenance on controller parts. These enclosures require gaskets and are so made that no dust or dirt can enter them. (See Fig. 2)

Weather-resistant, drip-tight, water-tight, and submersible-type enclosures are necessary where the corresponding service conditions are factors in maintenance requirements.

For hazardous locations such as mines, refineries, cleaning plants, or wherever explosive atmospheres are present, the enclosures are of heavy construction. They are so designed that they will withstand explosions of the gases within the enclosure without damage to the enclosure and

CONTROLLERS

NO. _____ LOCATION _____

MANUFACTURER _____ CLASS _____

HP _____ VOLTAGE _____ PHASE _____ CYCLE _____

STYLE NO. _____ SERIAL NO. _____

OPERATING COIL STYLE NO. _____

TRANSFORMER STYLE NO. _____

RESISTOR STYLE NO. _____

STYLE NO. OF CONTACTS STATIONARY _____

MOVING _____

MOTOR

NO. _____ LOCATION _____

MANUFACTURER _____ TYPE _____

HP _____ VOLTAGE _____ PHASE _____ CYCLE _____ SPEED _____ RPM _____

SERIAL NO. _____ STYLE NO. _____ FRAME NO. _____

STYLE OF MOTOR BEARINGS FRONT _____ REAR _____

PULLEY DIA. _____ FACE _____ BORE _____ KEY WAY _____

STYLE NO. BRUSHES _____ BRUSHES _____ PER SET _____

CONTROLLER HISTORY

MOTOR HISTORY

Fig. 1—Sample Record for Controller and Motor maintenance

Note: This article is condensed from a forthcoming edition of the book *Controllers for Industrial Motors*, by L. E. Markle and H. D. James, to be published by McGraw-Hill Book Company.

Fig. 2—Gasketed motor starter for dusty locations

without permitting any flames to emerge from it to cause external fires and explosions. Oil immersed controllers also are used to prevent explosions in dangerous locations.

Where acid fumes or other highly corrosive atmospheres exist, maintenance work will be minimized if the controller parts are immersed in oil and the enclosure is protected by a suitable finish.

Clean Controllers Require Less Maintenance

Very few industrial controllers operate in clean places. Dust, dirt, oil and moisture—separately or in combination with each other—all create maintenance work. These substances reduce insulating distance across otherwise clean and dry surfaces. The surfaces collect dust and dirt that may cause sluggish mechanical action of electrical devices.

Accumulations of dust and dirt should be removed regularly either by vacuum or by compressed air. (Excessive air pressures should be avoided because sharp, small particles may be driven into some insulating materials.) Special attention may be required to remove the metallic dust that collects and adheres to the magnetized parts of the controller. Dirt, oil, and moisture sometimes are most easily removed by wiping with cloths and suitable solvents.

Moisture due to condensation may collect within an enclosure. Drainage holes are sometimes acceptable to relieve this condition. Heaters often are used to prevent moisture by condensation. The heaters are most essential when the controller is idle. When in operation the coils and resistors within the enclosure usually will provide enough heat to prevent condensation.

For inspection and easy repair work, all parts should be made as accessible as possible. It should be possible to renew contracts, coils, springs, and other important parts quickly and with few tools. Installations should be arranged so that all units are accessible for maintenance work (see Fig. 3).

Contacts

Every time contacts open or close they are subject to mechanical wear and electrical burning. Contact parts, therefore, are items that may require considerable maintenance depending upon operating conditions. The mechanical wear of contacts that operate every second may be more serious than the electrical burning (see Figs. 4, 5).

Contact Materials

Contacts are generally made of copper or silver. Certain other materials can be used for special applications but should be recommended by the manufacturer. These materials usually have higher resistance and less current carrying ability than copper or silver. Large contacts for heavy currents almost always are made of copper. They may use silver sections or inserts at the place where final contact is made to improve current carrying ability or reduce heating. Silver contacts generally are used on the small current carrying contacts of relays, electrical interlocks, pushbuttons, thermostats, pressure switches and similar devices.

Contact Surfaces

Contacts should be kept clean. This is especially true of copper contacts because the discoloration that soon appears on clean copper is not a good electrical conductor. It therefore increases the contact resistance, and often is the cause of serious heating of contacts. When contacts are renewed, it is important to clean the new contact if it is discolored, and the surface against which it is mounted.

The slight rubbing action and burning that occur during normal good operation generally will keep the contact surfaces clean enough for good service. Contacts that seldom open or close, however, readily accumulate the thin discolored surface that may cause heating.

The dense discoloration that soon appears on clean silver is a relatively good electrical conductor. It is not so necessary, therefore, to keep silver contacts clean except for appearance.

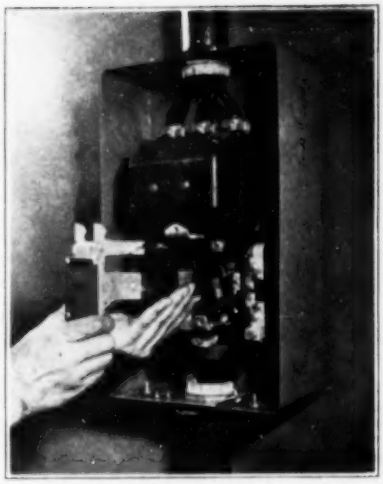

Fig. 3—Controller should be accessible for ease of maintenance

Burned Contacts

When contacts carrying excessive currents are closed or opened, or when contact motion is sluggish, the contact surfaces may be burned severely. If the burning causes deep pits or craters—or a very roughened surface—both the stationary and moving contacts should be renewed.

It is not essential or even desirable to have contact surfaces entirely smooth. Slightly roughened surfaces that appear during normal good operation, if clean, provide better contact area than smooth surfaces. Contacts with surfaces comparable to very coarse sandpaper may be considered in good condition.

Contacts that are dirty or excessively rough should be cleaned and smoothed with sandpaper (see Fig. 6). A fine file may be used, but be sure to maintain the true surface shape or contour of the original contact. The designer often spends much time and effort to determine the best contact shape. Changing the original shape by careless filing will leave high points or edges that may overheat. Emery paper should not be used to clean contacts. It is an electrical conductor. Furthermore, some particles become imbedded in the contact surfaces and cause unnecessary wear.

Worn Contacts and Contact Pressures

As contacts wear, the material in them gradually disappears both because of mechanical wear and electrical burning. During the wearing process the contact pressures decrease. This affects the current

Fig. 4—Mechanical Wear
Contact surface worn away mechanically —such a contact should be discarded

Fig. 5—Electrical Burn
This contact should be discarded—surface has been lost by burning

Fig. 6—Electrical Burn
Caused by interrupting excessive current —usable after filing silver surface

carrying ability which, if allowed to get too low, will cause overheating of the contacts. A small contact with suitable pressure will carry current with less heating than a large contact with little or no pressure. Reasonable provisions are made for the wearing of contacts when the original designs are made, but replacements eventually will be necessary. Manufacturers will furnish information on correct contact pressures for their devices. The contact pressures may be reduced either because of worn contacts or damaged contact springs. If contact springs have been overheated, they may be unable to provide sufficient contact pressure because the material has been weakened by the overheating. Contact pressures should be checked and maintained within suitable limits (see Fig. 7). Always replace both moving and stationary contacts.

Loose Contacts

Any loose electrical connection eventually will cause trouble. The bolts or fastening devices that hold contacts in place always should be tight. Normal expansion and contraction of metals due to temperature changes or excessive vibration will cause bolts or nuts to become loose. Frequent checking for loose contacts is advisable.

The life of oil immersed contacts is generally shorter than that of contacts operating in air. Frequent inspection of oil immersed contacts is important.

Welding of Contacts

Few contacts close without some bounce or rebound when they first come together. This is due to the reaction of the contact springs as they are compressed to provide the final contact pressure. When the contacts bounce they may separate. At this time the contacts are carrying current and, even though the separation be very small, an arc is created. The arc may cause sharp projections of burned or roughened contact surfaces to overheat and may weld or "freeze" the contact surfaces together. Other causes of contact welding are excessive currents when contacts close or open, insufficient contact pressure, sluggish operation either when closing or opening, and momentary closure of contacts with little or no pressure applied.

Silver contacts will weld more readily than copper ones. Well-designed contacts, properly applied, reduce this hazard to a minimum.

Contactor and Relay Coils

Coils provide the electro-magnetic pull that causes the contacts of relays and contactors to open or close. Series coils generally carry heavy currents and have relatively few turns of rather heavy copper. Shunt coils have many turns of insulated wire. They generally are impregnated in a vacuum or under pressure with insulating compounds and are covered with insulating tapes or materials. The impregnating compounds produce a firm but resilient binding material that prevents cracks when temperature changes occur. The impregnation process eliminates air pockets within the winding—making the coil a solid mass that is better able to radiate heat and less subject to mechanical injury.

Operating Voltages

Shunt coils for a-c devices are designed to close them at 85 per cent of rated voltage. Coils for d-c devices will close them at 80 per cent normal voltage. Any coil may be expected to withstand 110 per cent rated voltage without overheating.

A coil with an open circuit will not operate the contactor or relay. The questionable coil should be replaced immediately by one that is known to be satisfactory. The questionable coil then can be checked for open circuits.

If some turns of a coil become short-circuited, the resistance of the coil will be reduced and more current then passes through the coil. The increased current will cause higher operating coil temperatures and frequently causes coil burnouts.

Over- and Under-Voltage

Coils should be operated at rated voltage. Overvoltage on coils causes them to operate at a higher temperature that unnecessarily shortens coil life. Overvoltage also operates the contactor or relay with unnecessary force, causing more mechanical wear and bounce when closing.

Undervoltage on coils causes contactors and relays to operate sluggishly. The contact tips may touch but the coils may be unable completely to close the contacts against the contact spring pressure. Under these conditions, the contact pressure is below normal and the contacts may overheat and weld together.

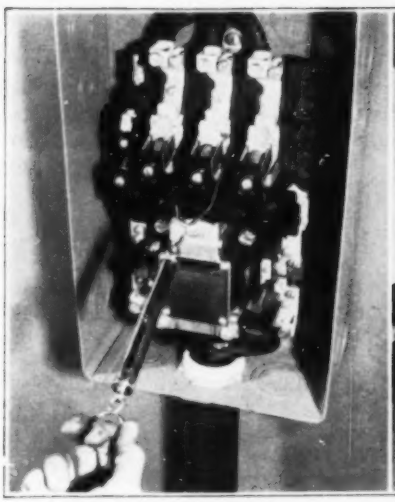

Fig. 7—Contact Springs
Measure contact spring pressure and maintain within recommended limits

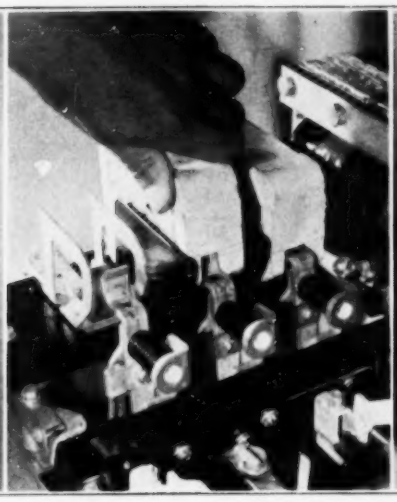

Fig. 8—Arc-rupturing Parts
These must be in proper position in respect to contacts when replaced

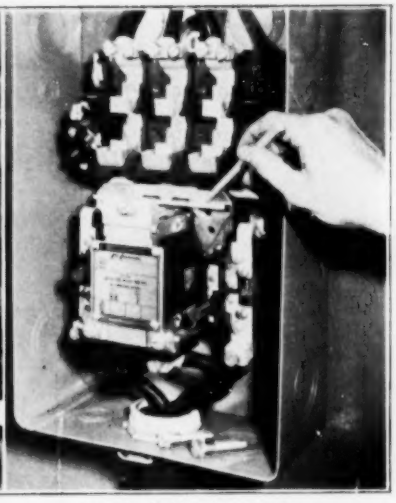

Fig. 9—Knife-edge Bearings
Opening and closing action wipes bearing surface and removes dust and dirt

Due to the magnetic air-gap and the characteristics of a-c circuits, the coil current of an a-c contactor is much higher while the contactor is closing and the air-gap is larger than after the contactor has closed and the air-gap is zero. Since the closing time is short, a-c coils are designed to withstand the closed conditions. They soon will overheat if the unit is blocked, or if the voltage is too low to close it and the coil remains energized with the large air-gap in the magnetic circuit. Freely operating parts will avoid such coil burnouts. D-c coils are not subject to these conditions because the coil currents are constant at all times.

Arc Rupturing Parts

When contacts are expected to open circuits carrying currents that are difficult to interrupt, they are equipped with arc-rupturing parts. The arc-rupturing parts generally surround the contacts and must be so made that they are easily moved out of position, or removed entirely to inspect and replace both moving and stationary contacts. To be effective, the arc-rupturing parts must be in a definite position with respect to the contacts. Hence the arc-rupturing parts always should be returned to the proper position if removed for any reason (see Fig. 8).

Shunts

The fine strands of flexible shunts sometimes break where the shunt bends. The unbroken strands must then carry the entire current. If many strands break, the unbroken ones become overloaded; they overheat and eventually burn. Frayed shunts should be replaced.

Bearings

Contactor and relay bearings are designed to require no lubrication, except for bearings of master switches, drum controllers and similar units. If lubricated, the accumulation of oil and dirt in contactors on relays may cause sluggish mechanical action that impairs the arc-rupturing qualities of the device or causes welding of the contacts.

The moving parts of contactors and relays should move freely in bearing surfaces without any evidence of tightness or friction. Periodic inspections to avoid friction in the moving parts is desirable.

Devices sometimes move vertically and therefore have no turning motion. The motion must be guided, and the guiding surfaces are comparable to bearing surfaces. Friction or magnetic sticking at these surfaces should be avoided.

Some designs, see Fig. 9, use knife-edge bearings. Here the opening and closing action of the device "wipes" the bearing surface, keeping it clean.

Magnetic Sticking

When operating coils are de-energized, some residual magnetism remains in the magnetic circuit. This residual magnetism sometimes is strong enough to hold the device closed after the coil is de-energized. This condition occurs most frequently on small devices on which contact spring pressures and moving parts are light. Magnetic sticking causes erratic, unsatisfactory, and sometimes dangerous operation. It can be avoided by adding a non-magnetic shim in the magnetic circuit.

Dashpots

Air or oil dashpots are used to retard motions. They are machined to close clearances and must be kept clean and free to move. The proper amount and kind of oil always should be kept in oil dashpots. Since the viscosity of oil changes with temperature, substitute oils should not be used.

Noisy Contactors and Relays

When the voltage on the coil of an a-c contactor or relay passes through zero, its magnetic pull or holding power is zero and the device starts to open. The voltage, however, is soon effective in the opposite direction and the device is again pulled closed. This operation causes a humming noise in any a-c operated device, and a decided chattering noise in a defective unit. The otherwise objectionable chattering is eliminated and the device is kept closed by the use of a shading coil, usually imbedded in the laminated magnetic circuit of the device. Such a coil can be seen in Fig. 3. The shading coil produces enough out-of-phase-flux to provide holding power to maintain the device closed during the short period when the main flux is zero. Even with shading coils in use, the air-gap surfaces must be free from dirt and well fitted to avoid objectionable noise. Broken shading coils are ineffective and cause noisy operation.

For quiet operation of a-c contactors, it is necessary to provide well-fitted surfaces at the air gap. Any dirt in this area introduces a greater

Fig. 10—Vibration loosens Resistor terminals. Check periodically for tightness

air-gap when the unit is closed, increases the duty imposed upon the shading coil, and results in more noisy operation. To prevent rusting of the fitted surfaces at the air-gap, these devices are often shipped with a small amount of grease or oil on them. This lubrication may cause a "seal" that makes them sticky and sluggish in opening when first put into service. These surfaces, therefore, should be wiped clean before the units are placed in service.

D-c coils are not subject to a zero voltage condition, hence they are always quiet. For this reason, a-c current-carrying contactors equipped with d-c operating coils will operate quietly.

Loose Connections

Loose connections of any kind should always be avoided on electrical circuits and apparatus. An open circuit or an unreliable one may cause much lost time and production because they are often very difficult to find.

A loose connection causes a poor contact of high resistance generating heat. The copper oxide or discoloration increases the resistance of the contact surface, causing still more heating. The effect always is cumulative, and the heating increases until the parts overheat, deteriorate, or burn.

A loose connection on a thermally operated device, such as the heater of a thermal overload relay, may, because of the external heat developed near the heater, cause the overload relay to trip and stop a motor when the motor is not overloaded.

Loose connections frequently develop on the terminals of resistors (see Fig. 10), because the alternate heating and cooling of the resistors cause temperature changes enough to loosen the bolts or nuts that clamp the connections to the resistor terminals. Excessive vibrations also may cause loose connections. The fact that a connection was once tight is no assurance that it will remain tight. Periodic inspections are advisable.

Excessive Temperatures

Overheated parts always indicate trouble. It is, however, often difficult to know when temperatures are excessive.

Resistors are operated safely at 350°C rise above ambient temperature, but insulated coils generally are restricted to 85°C above ambient. Solid copper contacts are limited to a rise of 65°C and copper bus work to 50°C rise.

Copper parts that are very discolored have been, or are, too hot. When in doubt, temperature should be measured by thermometer or by other means (see Fig. 11). It is best to know what the permissible temperature is and then measure it.

Thermally-operated overload relays should be in approximately the same ambient temperature as the motors they protect. If the relay is in a higher ambient temperature than the motor, it will trip when the motor is not overloaded. If the relay is in the lower ambient temperature, it may not trip in time to protect the motor. If the ambient temperatures must be different, some compensation for the difference can be made by proper selection of the overload relay heaters, or by providing a relay that compensates for the difference.

Grounds

Grounds are both useful and undesirable. The desirable ones are maintained easily because they require only good contact connections. An unexpected ground, however, is a serious personnel hazard.

Constant vigilance is required to prevent and eliminate undesirable grounds. They cause operating troubles, erratic, and dangerous operating circuits. Because of them motors may start unexpectedly; motors may not stop when they should; overload and other protective features may be made ineffective.

Grounds often occur in pushbutton boxes or similar confined spaces, where stray strands of wire may make contact at incorrect places. They occur when wires become chafed due to vibration on rough edges, such as conduit entrances. Conduits sometimes become wet from condensation or other reasons, and the insulation on the wires becomes watersoaked and of low insulating value. Conduits should, therefore be installed so that moisture within them will always drain

away. It sometimes may be necessary to remove the wires, clean the conduits, and install new wiring. Clean and dry conditions always reduce maintenance.

Summary

The following points are important for good maintenance:

1. Do everything possible for the safety of personnel.
2. Initial installation should be tested and proved satisfactory before it is accepted.
3. An adequate supply of correct renewal parts should be available.
4. A systematic program of inspection and maintenance work should be used.
5. Enclosures should be chosen for the operating conditions.
6. Keep controllers clean and dry.
7. Replace contacts that are worn very thin or badly burned and pitted. Replace contacts by pairs.
8. Maintain correct contact pressures.
9. Contacts should be kept clean. Do not change contact shape by rough filing or grinding.
10. Keep contacts and all connections tight.
11. Do not oil contactor or relay bearings, but keep these units clean and with no friction in the moving parts.
12. Operate coils at rated voltage. Both overvoltage and undervoltage conditions are undesirable.
13. Keep arc-rupturing parts in good condition and in correct operating positions.
14. Replace frayed and worn shunts.

Fig. 11—Controller coil temperature important. Use thermometer to measure temperature if in doubt about overheating.

15. Keep all dashpots clean. Be sure oil dashpots have correct oil in them.
16. Correct conditions that cause excessive temperatures. Measure the
17. Be alert for undesirable grounds on all circuits and eliminate them.

A Successful Suggestion Plan

In 1952 employees of Westinghouse Electric Corp. received $144,057 for suggestions made by the employees which were found acceptable to the Corporation. In all 8,346 suggestions proved to be money winning ideas put to use by Westinghouse under its Suggestion Plan. The record year for the plan was 1948 when $147,557 was paid out to Westinghouse employees making useful suggestions.

We are publishing this condensation of a report by Westinghouse to show that Suggestion Plans have been found to pay by large corporations and are being continued.

In the past we have advocated such employee suggestion plans for water and sewage utilities and have often wondered just how extensively such plans have been tried in the water and sewage utilities. What has proven good for large private enterprises should also prove of value in municipal utility operations—or, so it seems to us.

Purdue Offering a Number of Fellowships in Sanitary Engineering

Purdue University announces the availability of a number of Research Fellowships in Sanitary Engineering to become available June 15, 1953, or Sept. 12, 1953, when the fall semester begins. Salary for half-time employment on the research project of the candidate's choosing will be $100 to $150 per month; or, for quarter time employment, $50 to $75 per month.

Applicants must have a B.S. degree in Civil, Mechanical or Chemical Engineering if seeking the M.S. degree; or, an M.S. degree if seeking a Ph.D. degree. The M.S. degree can be obtained in 12 months while being employed on a research project half time if the candidate is qualified and is a serious student.

For further information as to the several types of research projects now available or to become available within the year, and other details, write Prof. Don E. Bloodgood, Dept. of Sanitary Engineering, Purdue University, Lafayette, Ind.

When something goes wrong, it is much more important to talk about who is going to fix it than who is to blame for it.

THE EDITOR'S COMMENTS

A Rarity Amongst Resolutions

It is indeed a rarity when a governing body of a municipality goes on record with words of praise and commendation of a public utility. More rarely still has such praise "for maintenance of the highest standards, and for its attitude of good citizenship" been publicly directed to a privately owned water company and made the subject of a special resolution drawn, recorded and publicized by a mayor and city council. Such, however, has been the exceptional case in mushrooming Baton Rouge, Louisiana.

The deserving recipient of such open recognition is the Baton Rouge Water Works Co. Resolution No. 161 of the City Council of Baton Rouge has only recently come to our attention. This form of proclamation is such a rarity as to merit its reproduction on this page, with added congratulations from this magazine to D. R. Taylor, Engr. and Genl. Manager of the water company, and those of his staff who have done their job so well as to win such praise of their company by the city.

We have reason, too, to give a measure of credit also to Louis R. Howson, and his firm, for their guidance and advice to the company prior to and during the period of great expansion and added betterments to the Baton Rouge system which brought forth the commendation of the city council as well as the citizenry of Baton Rouge. To Howson goes an extra measure of credit for his personal selection of "Doc" Taylor to manage and operate the Baton Rouge Water Co. At the time we didn't like it much though, because of a certain desire to keep capable Virginians for Virginia. We felt then, and correctly said in comments made at the time in connection with publication of the announcement, that Roanoke's loss was Baton Rouge's gain.

One of the major reasons for the city's praise of the water company has been the outstanding example of cooperative efforts in keeping up with the city's expansion of annexed territory and new housing. This program was made possible through an investment of an additional $2,000,000 by the company for main extensions and other additions and betterments to provide adequate fire protection along with an ample supply of water. At the same time the city spent $1,120,000 for expansion and improvement of its fire fighting equipment and facilities. Where Baton Rouge citizens felt the results in a most real way was the reduction of fire rates on frame dwellings in the new areas to less than one half the pre-betterment rates. Baton Rouge now has twice the number of "capable" fire hydrants than it had four years ago. To serve a population increase of 215 per cent also involved a 44 per cent mileage increase in water mains to serve the 77 per cent growth of active accounts, necessitating an increase of 45 per cent in supply capacity.

To accomplish all of this in a four year expansion period required some doing. The official recognition won by the Baton Rouge Water Works Co. has come from an appreciative City Council.

RESOLUTION No. 161

WHEREAS, during the recently completed expansion of the fire fighting facilities in the City of Baton Rouge, an important part was played by the Baton Rouge Water Works Company, as well as by official agencies and citizen committees; and

WHEREAS, the Baton Rouge Water Works Company offered full cooperation and carried out a large and difficult program to increase its mains, hydrants and pumping capacity, which form a vital part of the fire defenses of this City; and

WHEREAS, the company performed this expansion so satisfactorily that it maintained its Class I rating by the National Board of Fire Underwriters upon completion of the program, and has further declared its policy to be continued expansion as Baton Rouge grows;

NOW, THEREFORE, The City Council of the City of Baton Rouge expresses the sincere appreciation of its members to the officials and employees of the

BATON ROUGE WATER WORKS COMPANY

for a job well done, and congratulates the company for its maintenance of the highest standards, and for its attitude of good citizenship.

IN WITNESS WHEREOF, the Mayor-President of the City of Baton Rouge and the Parish of East Baton Rouge and the members of the City Council have hereunto set their hands and caused to be affixed the great seal of the City of Baton Rouge this thirteenth day of August, 1952.

More About the Weather

The predictions of H. P. Gillette on the weather ahead for 1953 in his article "Severe Winter Ahead," published in our December 1952 issue, and our subsequent editorial comment, are bringing in letters indicative of the correctness of the Gillette predictions of a winter of exceptionally heavy precipitation.

The heavy rainfall of the Northwest, the destructive flash storms on the Pacific Coast, the costly shipwrecking storms and inundation of parts of the British Isles and Holland, the amount of precipitation in the central northerly areas, New York with its drenching 8.0 inches of rainfall for March establishing an all-time record for the month. Even as these comments are being written in mid-April, Nebraska and Iowa are being pounded by blizzard-like snow storms. The Great Lakes and central west regions are experiencing cold rains and winds of gale force as far south as St. Louis, while northern Texas shivers and freezing temperatures reach down to southern Virginia. These are but some of the occurrences involving abnormally heavy precipitation during the winter of 1952-53.

Most of this has happened since our editorial pointing out that much of it had already occurred through January 1953 and warning of the likelihood of more to come. Since then the evidence proving the correctness of Mr. G's predictions has continued to mount. Over the nation as a whole there have been a few exceptions but these have been spotty and exceedingly few. From here on we are "ready to buy" H.P.'s weather predictions, although we admit our utter inability to understand most of his theories, his computations and, perhaps, a bit of the "crystal gazing" to make it the more interesting.

L. H. Enslow

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- Dependable
- Economical
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"PAKAGE" SEWAGE PLANTS

A unit specifically developed and planned for small community housing developments or industrial plants. Handles sewage flows from 50 to 500,000 gallons per day in single or multiple units. Excellent for population equivalents from 100 to 5000. No specially trained plant operator required.

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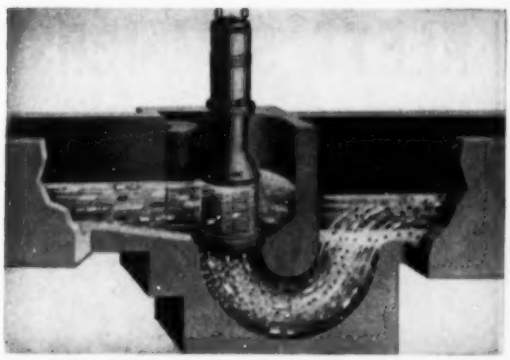
Swing Diffusers assure uninterrupted operation without costly stand-by tanks. Individual swing units are easily raised for inspection and diffuser cleaning. Lowest cost simplified cleaning restores new tube performance, permitting maintenance of lower blower pressure. Wide-band air diffusion means no unaerated center core.



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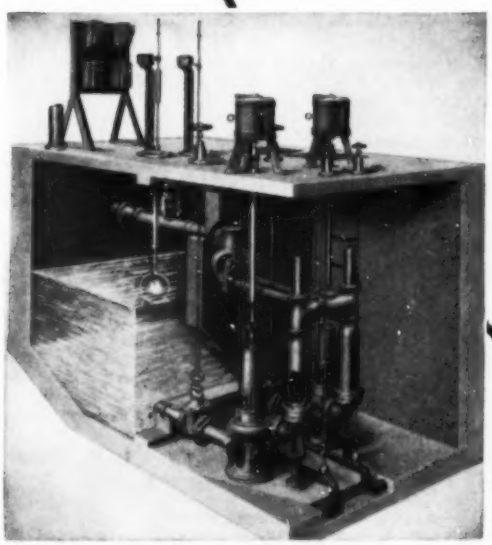
Sewage solids are automatically screened and cut without removal from the line of flow by the Comminutor. Eliminates handling, burial or incineration of screenings. No odors, unsightliness or fly nuisance.



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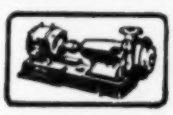
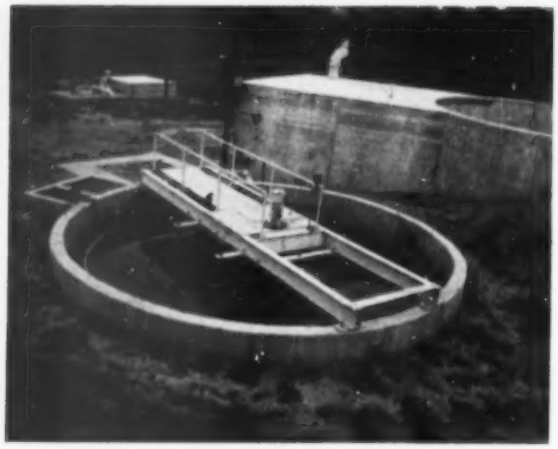
The proven clog-proof pump for handling raw sewage or liquids containing coarse or stringy matter. Incoming sewage flows through idle pumps. Incoming solids are retained on a screen. Screen is backwashed when pump starts — all solids are carried to discharge pipe. Pump handles only strained liquids.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION



622 DIVERSEY PARKWAY CHICAGO 14, ILLINOIS



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70 to 80% actual detention of the theoretical results in 70 to 80% removals of the S.S. by primary SPIRAFLO clarifiers without the use of pre-aeration or the use of chemicals. Can you beat it?

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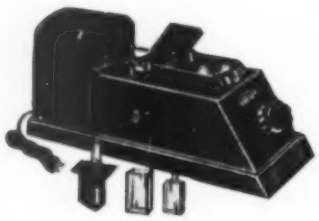
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color turbidity can be developed in proportion to substance to be determined.

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Meetings Scheduled

May 10-15—Grand Rapids, Mich. *(Exhibits and Technical Sessions—Auditorium. Hotels—Various*)* AMERICAN WATER WORKS ASSOCIATION (73rd Annual Convention). Exec. Sec'y, Harry E. Jordan, 521 Fifth Ave., New York 17, N.Y.
*(*For reservations apply A.W.W.A. Office)*

May 12—Grand Rapids, Mich. *(Hotel Pantlind)* MICHIGAN SECTION A.W.W.A. (Business Meeting to be held during A.W.W.A. Convention). Sec'y, T. L. Vander Velde, Dept. of Health, Lansing 4, Mich.

May 20-21—Ocean City, Md. *(Commander Hotel)* MARYLAND-DELAWARE WATER & SEWERAGE ASSOCIATION. Sec'y, W. M. Bingley, 2411 N. Charles Street, Baltimore, Md.

May 21-22—Richmond, Va. *(Hotel Jefferson)* VIRGINIA INDUSTRIAL WASTES & SEWAGE WORKS ASSOCIATION. Sec'y, J. L. Hamrich, Jr., 415 W. Franklin St., Richmond, Va.

June 3-5—Peoria, Ill. *(Hotel Pere Marquette)* CENTRAL STATES SEWAGE & IND. WASTES ASSN. Sec'y, A. P. Troemper, Ill. Water Board, Springfield, Ill.

June 4-5—Laconia, N.H. *(Laconia Tavern)* NEW ENGLAND SEWAGE & INDUSTRIAL WASTES ASSOCIATION. (Spring Meeting). Sec'y, Stephen M. Hurley, Jr., 331 State Office Building, Providence, R.I.

June 8-9—Rochester, N.Y. *(Sheraton Hotel)* NEW YORK SEWAGE & INDUSTRIAL WASTES ASSOCIATION. Sec'y, Ralph C. Sweeney, 21 N. Broadway, White Plains, N.Y.

June 8-12—University, Ala. *(Univ. of Ala.)* ALABAMA WATER & SEWAGE WORKS ASSOCIATION. Sec'y, Alex O. Taylor, Box 69, Auburn, Ala.

June 8-12—University, Ala. *(Univ. of Ala.)* ALABAMA SHORT COURSE SCHOOL. (Sponsored by Alabama Water & Sewage Assn.) Director, D. H. McLean, Box 3752, University, Ala.

June 10—Bath, Me. MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, 15 Bowdoin St., Winthrop, Me.

June 10—Martinsville, N.J. *(Martinsville Inn)* NEW JERSEY SECTION A.W.W.A. (Summer Outing & Inspection of Johns-Manville Research Center, Finderne, N.J.—Luncheon at Inn). Sec'y, C. B. Tygert, Box 178, Newark 1, N. J.

June 17-19—Hershey, Pa. *(Hotel Hershey)* PENNSYLVANIA SECTION A.W.W.A. Sec'y, L. S. Morgan, Dept. of Health, Greensburg, Pa.

June 17-19—Akron, O. *(Mayflower Hotel)* OHIO SEWAGE & INDUSTRIAL WASTES TREATMENT CONFERENCE. Sec'y, Ward E. Conrad, 301 Ohio Dept. Bldg., Columbus, O.

June 18—York Harbor, Me. *(Marshall House)* NEW ENGLAND WATER WORKS ASSOCIATION (June Conference). Sec'y, Jos. C. Knox, 73 Tremont St., Boston, Mass.

June 22-26—Gainesville, Fla. *(Univ. of Fla.)* AMERICAN SOCIETY FOR ENGINEERING EDUCATION. (61st Annual Convention). Rachel Albertson, College of Engineering, Univ. of Florida, Gainesville, Fla.

June 29-July 3—Atlantic City, N. J. *(Hotels Chalfonte and Haddon Hall)*
AMERICAN SOCIETY FOR TESTING MATERIALS. Sec'y, R. E. Hess, 1916 Race St., Philadelphia, Pa.

Aug. 12—Sanford, Me.
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, 15 Bowdoin St., Winthrop, Me.

Aug. 24-26—State College, Pa.
PENNSYLVANIA WATER WORKS OPERATORS ASSN. Sec'y, R. R. Kountz, Penna. State College, State College, Pa.

Aug. 26-28—State College, Pa.
PENNSYLVANIA SEWAGE & INDUSTRIAL WASTES ASSN. Sec'y, B. S. Bush, Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Sept. 1-5—Winnipeg, Can. *(Royal Alexandria)*
MINNESOTA SECTION A.W.W.A. Sec'y, L. N. Thompson, Water Department, St. Paul 2, Minn.

Sept. 2-4—Ames, Ia. *(Iowa State College)*
IOWA SEWAGE WORKS ASSOCIATION. Sec'y, Leo Holtkamp, P.O. Box 310, Webster, Ia.

Sept. 3-4—Morgantown, W. Va. *(Hotel Morgan)*
WEST VIRGINIA SECTION A.W.W.A. Sec'y, H. K. Gidley, State Dept. of Health, Charleston 5, W. Va.

Sept. 10-11—Lake Placid, N.Y. *(Lake Placid Club)*
NEW YORK SECTION A.W.W.A. Sec'y, R. K. Blanchard, 50 West 50 St., New York, N.Y.

Sept. 10-11—Cleveland, O. *(Hotel Cleveland)*
OHIO SECTION A.W.W.A. Sec'y, M. E. Druley, Dayton Power & Light Co., Wilmington, Ohio.

Sept. 21-23—Owensboro, Ky. *(Owensboro Hotel)*
KENTUCKY-TENNESSEE INDUSTRIAL WASTES & SEWAGE WORKS ASSOCIATION. Sec'y, R. Paul Farrell, 420 Sixth Ave. N., Nashville 3, Tenn.

Sept. 21-23—Owensboro, Ky. *(Hotel Owensboro)*
KENTUCKY-TENNESSEE SECTION A.W.W.A. Sec'y, J. W. Finney, 420 6th Ave. N., Nashville, Tenn.

Sept. 21—Santa Fe, N.M. *(Hotel La Fonda)*
ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION. Sec'y, C. E. Harness, 271 City & County Bldg., Denver, Colo.

Sept. 22-23—Santa Fe, N.M. *(Hotel La Fonda)*
ROCKY MOUNTAIN SECTION A.W.W.A. Sec'y, George J. Turre, Board of Water Commissioners, P.O. Box 600, Denver, Colo.

Sept. 22-24—Milwaukee, Wis. *(Hotel Pfister)*
WISCONSIN SECTION A.W.W.A. Sec'y, L. A. Smith, City Hall, Madison 3, Wis.

Sept. 23-25—Edmonton, Alberta *(Macdonald Hotel)*
WESTERN CANADA WATER & SEWAGE CONFERENCE. (Operators' School Sept. 23) Sec'y, W. J. Waddell, 617-7th Ave. East, Calgary, Alberta.

Sept. 27-29—Excelsior Springs, Mo. *(Elms Hotel)*
MISSOURI SECTION A.W.W.A. Sec'y, Warren A. Kramer, State Office Building, Jefferson City, Mo.

Sept. 28-30—Poland Spring, Me. *(Poland Spr. House)*
NEW ENGLAND WATER WORKS ASSOCIATION (72nd Annual Convention). Sec'y, Jos. C. Knox, 73 Tremont St., Boston, Mass.

Oct. 4-6—Jackson, Miss. *(Hotel Heidelberg)*
ALABAMA-MISSISSIPPI SECTION A.W.W.A. Sec'y, Chas. W. White, State Dept. Health, 537 Dexter Ave., Montgomery, Ala.

Oct. 11-13—Miami, Fla. *(Hotel McAllister)*
FLORIDA SECTION A.W.W.A. Sec'y, William W. Aultman, Dept. of Water & Power, Box 316, Coconut Grove Sta., Miami 33, Fla.

(Continued on page 106)

NEW DEVELOPMENT INCREASES
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Increase the oxygen content in:
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CUT COSTS ON UNDERGROUND PIPING JOBS

...with a GREENLEE PIPE PUSHER

Installing pipe underground is quick and simple this way. With a GREENLEE Hydraulic Pipe Pusher *one man* pushes pipe through the ground—under streets, railways, walks, lawns, floors. Saves time, cuts costs through elimination of extensive ditching as just a short trench accommodates the Pusher. No tearing up of pavement, lawns, floors... eliminates tunneling, back-filling, tamping, repaving. Cuts job time to a fraction. Pusher often pays for itself through timesavings on first job or two.

No. 790 GREENLEE PUSHER For 3, 4 to 4-inch pipe. Six speeds—5,600 to 40,000 lbs. pushing pressure.

No. 795 GREENLEE PUSHER For pipe larger than 4-inch, concrete sewer pipe, large drainage ducts. Six speeds—25,000 to 150,000 lbs. pushing pressure.

POWER PUMP For both sizes of GREENLEE Pushers. Pushes pipe at rate of two feet per minute.

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Get facts on timesaving Greenlee tools now. Write Greenlee Tool Co., Division of Greenlee Bros. & Co., 2245 Columbia Avenue, Rockford, Illinois, U. S. A.

Pickups from "Sanitary Engineering News"

Don E. Bloodgood, Editor

Before President Truman bowed out of office he signed into law a measure involving federal expenditure of about $2,000,000 over the next five years for development of a process for converting sea water to fresh water.

* * *

In their original state algae do not seem to be harmful, but under certain conditions they become over-grown and tend to decompose. During this process one species of algae appears to release a poison substance. A number of animals in the Sturgeon Lake (Ontario) region have died from drinking water thus contaminated.

* * *

It is reported that in St. Louis 6 inch water mains can be laid for $4.38 per ft. In Hartford, Conn. the cost is $4.49.

* * *

There are 226 river basins in the U.S. and there are 22,000 sources of pollution in these same basins.

* * *

Have you ever tried siliconing pipettes and burettes in order to make them drain completely clean and dry?

* * *

Kansas City, Mo., sells water to some 38,000 users outside its corporate limits on a demand and volume basis that is unique in water works practice. Charges are based on daily and hourly maximum rates during the summer period plus a charge for cubic feet used.

* * *

In Charlotte, N. C. a surcharge to industry of $23.34 per 1000 lb. of B.O.D. is made to cover the fixed charges and amortization costs of additional sewage plant capacity. The cost per 1000 lb. of B.O.D. in excess of 250 ppm. is computed from the actual cost per 1000 lb. of B.O.D. removed from the combined sewage and industrial wastes as experienced at the municipal treatment works during the preceding fiscal year.

* * *

It is reported to be impossible to determine the amount of dissolved oxygen in water that contains tannin.

KRALOY PIPE & FITTINGS

COMPLETE
DISTRIBUTION SYSTEMS
MAINS, SADDLES, SERVICES

No Corrosion!

Kraloy will not rust, is impervious to all types of soils, and is not subject to galvanic corrosion.

Low-Cost Installation

No welding or field wrapping is necessary. Installations are simple, rapid, inexpensive.

No Maintenance

Properly installed Kraloy systems eliminate all maintenance causes except damage by excavating equipment.

- LIGHT-WEIGHT. Easier to handle. 8 times lighter than steel, 15 times lighter than copper.
- TRANSPARENT. Permits visual inspection of joints.
- GREATER CARRYING CAPACITY. Smooth, frictionless. Can carry 20% more than steel pipe.
- NON-TOXIC. Does not impart a taste to water.

Kraloy is the most experienced manufacturer of plastic pipe and fittings for underground water lines. Kraloy in use by over 100 water utilities.

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Write for technical data and installation details

Kraloy Plastic Pipe Co., Inc.
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Gentlemen: Please send me complete information on Kraloy Pipe and Fittings.

NAME_____
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CITY_____ ZONE____ STATE_____

Maine and Ohio both have new stream pollution control laws.

* * *

Hammond has reinforced its water system with 14 miles of cast iron pipe.

* * *

Of Cincinnati's dwelling units, 35,910 do not have their own bath or shower.

* * *

The State of New York has announced that the Class F stream is one that will be designated for sewage and waste disposal as its best usage. Is this good?

* * *

New Standards Approved for Short-Body C. I. Fittings

A new American Standard for short-body cast-iron fittings for water distribution has been published and may be obtained from the American Water Works Assn., 521 Fifth Ave., New York 17, N.Y., upon advance remittance of 35c. Known as ASA A21.10-1952, the specification was jointly sponsored by the American Gas Assn., American Society for Testing Materials, New England Water Works Assn., and American Water Works Assn., and has received the official approval of the American Standards Assn.

The fittings are designed for 250-psi water pressure plus water hammer, and represent a radical change in design from the previous standard, which was established by two of the sponsoring agencies (NEWWA and AWWA) in 1908. The new short-body fittings are lighter, cheaper, and more compact than the earlier bell-and-spigot fittings, and are better adapted for distribution work in city streets congested with utility and other structures.

"Madam are you sure that it's your new girdle, and not our missing rubber pipe joint seal?"

Millions of users agree—

you cut more pipe with less work with RIDGID Heavy-Duty Cutters

There's a big difference in pipe cutters—and you're sure of it the first time you slap a RIDGID on a pipe (any kind) and see how easily cleanly it rolls through the metal. Beautifully balanced for easy action. Factory tested for perfect tracking—and guaranteed warp-proof housings of special malleable hold it. High alloy thin-blade or heavy-duty cutter wheels that leave practically no burr. You cut pipe fast with least effort. Ask your Supply House for the more-for-your-money RIDGID.

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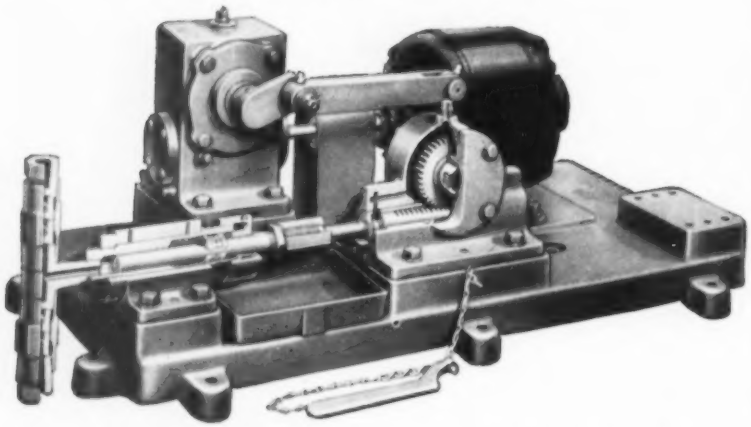
RIDGID
Work-Saver Pipe Tools

For precisely controlled metering and proportioning of small volume flows...



...the HILLS-McCANNA "U" Type Proportioning Pump

• The Hills-McCanna "U" Type Pump is designed to continuously meter and proportion small flows of the order of 0.10 to 24 gallons per hour per feed. Its accuracy and reliability suit it for research, pilot plant operation and full scale processing alike. The "U" type pump is suitable for batch or continuous operations.

Typical examples of "U" type pump applications include:

- Continuous addition of air entraining agents during cement manufacturing operations.
- Continuous injection of internal phosphate treatment and sodium sulphite oxygen scavenging in boiler plant water treatment.
- Injection of gasoline gum inhibitors into finished gasoline.
- Proportioning low molecular weight polymers and catalyst solution in resin research.

The new "U" Pump Catalog, UP-52, gives full information on the "U" type pump plus extensive application data including specific service recommendations for handling over 300 substances. Write for your copy, today. HILLS-McCANNA CO., 2357 W. Nelson St., Chicago 18, Ill.

HILLS-McCANNA

metering and proportioning pumps

Also Manufacturers of: Saunders Patent Diaphragm Valves

Force Feed Lubricators • Magnesium Alloy Sand Castings

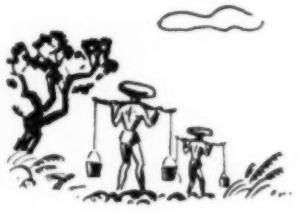
Hong Kong Sewer in Hollywood

The money spent recently by Columbia Pictures for installing a new drainage system to protect its ranch acreage from future torrential rains, is proving a good investment in more ways than one. Under the art direction of Ross Bellah, the system has been turned into a simulation of underground sewers in the city of Hong Kong for the Wallace MacDonald production of "Target—Hong Kong." Black tarpaulin has been stretched for 200 yards over the largest and deepest drain to protect the set depicting the tunnel. Water is supplied from the ranch's huge tank usually reserved for the making of storms at sea.

Tentative Standards for Steel Pipe Flanges

Specifications for steel pipe flanges adopted by the American Water Works Association for steel water pipe are now available, in booklet form. The standard includes information on dimensions, pressure ratings, and material.

Known as AWWA C207-52T, the eight-page booklet may be obtained from the American Water Works Association, 521 Fifth Avenue, New York 17, N.Y., upon advance remittance of 25c.



Muddy water's cleaner, think many Chinese, so coolies who sell purified water by the bucket often have to dump in some mud before customers will buy, says a note in *Weekly Digest*.

Muddy Water's Cleaner?

Indianapolis Water Co.'s *"Water Lines"* lifted the above from *Weekly Digest*, and now we've lifted it from *"Water Lines."* Funny people, those Chinese!

On second thought, though, we can remember back more than a few years when the folks in Richmond, Va., were first served de-mudded James River water and they didn't like it too well. Said it lacked "substance." Folks in St. Louis, Mo., had about the same opinion of the Mississippi water when the new coagulation and settling plant went into operation.

NEW WATER & SEWAGE BOOKS

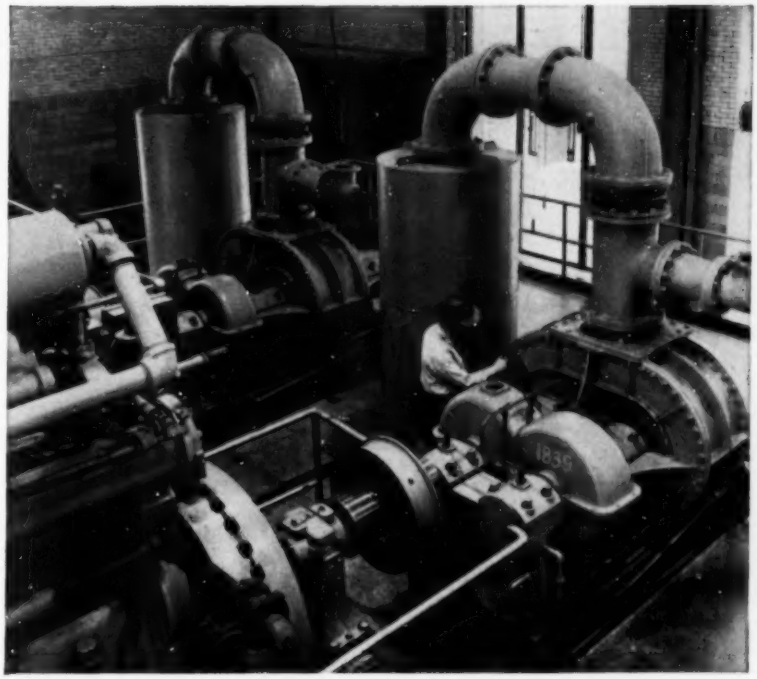
Sewerage and Sewage Treatment, (Seventh Edition). By Harold E. Babbitt. (John Wiley & Sons, Inc., New York, N.Y. $8.00).

In his preface, Professor Babbitt emphasizes that—"The practice and the art of sewage treatment continue to change, and to change relatively rapidly, owing to greater public interest and support of the principles of sanitation and of conservation, and to the activities of the increasing number of workers in the field." The new "streamlined" edition of 674 pages (29 chapters) has been modernized in many features.

Nomenclature has been extensively revised to conform with the recent *Glossary* of terms, data on sewerage census statistics have been brought up to date, and this edition includes new standard specifications for design published by various state Boards of Health. Design sections are modified by recent extensive studies on the hydraulics of street inlets, pumping station design data have been added—with details for building, layout and equipment. There is a new section on internal combustion engines, together with a discussion of dual fuel engines. The concept of chemical oxygen demand is introduced in this edition, greater emphasis is devoted to the importance of the dissolved oxygen curve, and a method for the computation of the minimum dissolved oxygen point is explained and illustrated.

Additional advantages of chlorination are presented, newer sewage treatment processes are described, and the chapter on industrial wastes has been thoroughly rewritten and expanded. Throughout the book, references are now footnotes to save time and make material more significant.

Professor Babbitt's book is an orderly presentation of material required for instruction and for reference; it is well illustrated and well documented. Few textbooks will give the student of sanitary engineering a viewpoint as modern and timely or as comprehensive in scope.



Recent installation of two R-C Rotary Positive Blowers in Northeast Sewage Treatment Plant. Capacity of each unit is 5,000 cfm.

CONSULT THE "Specialists" ON BLOWER PROBLEMS

One of the many reasons why Roots-Connersville Blowers are such prime favorites among sewage treatment engineers is their unquestioned reliability. In small plants, with only intermittent or part-time attendants, this is of prime importance. For installations handling large volumes, even a temporary breakdown could have serious results.

Another factor contributing to the popularity of R-C equipment is the *dual choice* provided by the exclusive *dual-ability line* of both Rotary Positive and Centrifugal designs. Because we build both, R-C Specialists have no prejudices—they can recommend whichever type is best suited to the specific job to be done.

The long-time, satisfactory performance of R-C installations comes from almost a century of specialized experience in handling air and gas. We have no other business—our time and facilities are 100% devoted to designing and building blowers, meters, gas pumps and related equipment. Much of this experience is in the sewage treatment field, in which we have more installations than any other company. So, when you have a problem of blowers, for new plants or for replacements, we suggest you call on the "Specialists" who are always at your service.

ROOTS-CONNERSVILLE
Exclusive Specialists in Handling Gas and Air

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Now there is a real solution to the problem of screening solids out of manufacturing waste water *before* it reaches the main sewage disposal outlets. SWECO Separators will screen from 90% to 100% of all solids from waste liquids on a production basis through screens from 50 up to 325 mesh. SWECO Separators are doing a job in the following and many other industries:

PULP & PAPER	LUMBER
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SWECO

SEPARATOR DIVISION
SOUTHWESTERN ENGINEERING COMPANY
4800 Santa Fe Avenue, Los Angeles 58, Calif. S-9

Meetings Scheduled

(*Continued from page* 101A)

Oct. 13-16—Miami, Fla. *(Municipal Auditorium)*
FEDERATION OF SEWAGE & INDUSTRIAL WASTES ASSN. (26th Annual Meeting), Exec. Sec'y, W. H. Wisely, 325 Illinois Bldg., Champaign, Ill.
(joint Meeting with)
FLORIDA SEWAGE & INDUSTRIAL WASTES ASSOCIATION. Sec'y, D. P. Schiesswohl, P.O. Box 210, Jacksonville, Fla.

Oct. 14—Rumsford, Me.
MAINE WATER UTILITIES ASSOCIATION (Annual Meeting). Sec'y, Earle A. Tarr, 15 Bowdoin St., Winthrop, Me.

Oct. 14-16—Waterloo, Iowa *(Hotel Russell Lamson)*
IOWA SECTION A.W.W.A. Sec'y, H. V. Pedersen, Municipal Bldg., Marshalltown, Iowa.

Oct. 18-21—Houston, Tex. *(Rice Hotel)*
SOUTHWEST SECTION A.W.W.A. Sec'y, L. A. Jackson, Robinson Auditorium, Little Rock, Ark.

Oct. 19-24—New York, N.Y.
AMERICAN SOCIETY OF CIVIL ENGINEERS (Annual Meeting). Sec'y, Wm. N. Carey, 33 W. 29 Street, New York 18, N.Y.

Oct. 20-23—Atlantic City, N.J. *(Chalfonte Hotel)*
PENNSYIVANIA WATER WORKS ASSOCIATION. Sec'y, W. A. Kufs, 510 Telegraph Bldg., Harriburg, Pa.

Oct. 22-24—Atlantic City, N.J. *(Madison Hotel)*
NEW JERSEY SECTION A.W.W.A. Sec'y, C. B. Tygert, Box 178, Newark, 1, N.J.

Oct. 26-29—New Orleans, La.
AMERICAN PUBLIC WORKS ASSOCIATION. Exec. Sec'y, Donald F. Herrick, 1313 East 60th St., Chicago, Ill.

Oct. 27-30—San Francisco, Calif. *(Palace Hotel)*
CALIFORNIA SECTION A.W.W.A. Sec'y, J. C. Luthin, 1113 Laurent St., Santa Cruz, Calif.

Oct. 28-30—Wilmington, Del. *(Hotel DuPont)*
CHESAPEAKE SECTION A.W.W.A. Sec'y, C. J. Lauter, 6955 33rd Street, Washington 15, D.C.

Nov. 4-6—Roanoke, Va. *(Hotel Roanoke)*
VIRGINIA SECTION A.W.W.A. Sec'y, W. H. Shewbridge, 708 State Office Bldg., Richmond 19, Va.

Nov. 9-11—High Point, N.C. *(Sheraton Hotel)*
NORTH CAROLINA SEWAGE & INDUSTRIAL WASTES ASSOCIATION. Sec'y, E. C. Hubbard, State Board of Health, Raleigh, N.C.

Nov. 9-11—High Point, N.C. *(Sheraton Hotel)*
NORTH CAROLINA SECTION A.W.W.A. Sec'y, E. C. Hubbard, State Board of Health, Raleigh, N.C.

Nov. 12-13—Lincoln, Neb. *(Hotel Capitol)*
NEBRASKA SEWAGE & INDUSTRIAL WASTES ASSOCIATION. Sec'y, Paul W. Mousel, 602 W. B. Street, McCook, Neb.

Nov. 8-13—New York, N.Y. *(Statler & New Yorker Hotels)*
AMERICAN PUBLIC HEALTH ASSOCIATION. Sec'y, Mrs. W. R. Walsh, A.P.H.A., 1790 Broadway, New York, N.Y.

Nov. 16-20—Stillwater, Okla. *(Okla. A. & M. College)*
OKLAHOMA WATER, SEWAGE & IND. WASTES SHORT COURSE. Sec'y, H. J. Darcey, State Dept. of Health, Oklahoma City, Okla.

Dec. 9—Waterville, Me.
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earl A. Tarr, 15 Bowdoin St., Winthrop, Me.

Dec. 13-16—St. Louis, Mo.
AMERICAN INSTITUTE OF CHEMICAL ENGINEERS. (Annual Meeting). Sec'y, F. G. Van Antwerpen, 120 East 41st St., New York 17, N.Y.

that only C-P-P* meets the BIG 3 REQUIREMENTS

Cleveland's Fire Chief knows how vital *high capacity* can be in a water line. Not long ago he said:

"Of the seven major factors in grading a city (for insurance), the most important is water supply. We get a lot of deficiency points from the underwriters because much of our 1,500 miles of water mains are old *and* tuberculation *has reduced their capacity."*

But Cleveland is solving this problem. Price Prestressed Concrete Pipe is now going in on a number of 16-inch, 24-inch, 30-inch and 36-inch supply lines.

Future fire chiefs won't have to worry about tuberculation or corrosion in these lines. Price Pipe *maintains* a high carrying capacity over the years because concrete has the highest flow coefficient of any pressure pipe structural material, and because the flow of water over concrete creates a slippery surface that actually *aids* the flow of water, rather than retarding it.

Price Pipe has long life too. Concrete buried under ground is as ageless as limestone. *Long life* with *continued high carrying capacity* is a tough combination to beat.

But Price Pipe has one other big plus value . . . *great strength.* It is safer from external loads, and sudden complete failure is all but impossible.

Add to these "Big 3" the other advantages of easy installation, easy tapping, watertightness, low original cost and low maintenance . . . and you can see why Cleveland specs now call for concrete bids on all lines 16 inch and over.

For all the facts on Price Pipe, write today.

only CONCRETE PRESSURE PIPE MEETS THE BIG 3 REQUIREMENTS

Price Brothers Company

1815 East Monument Avenue, Dayton 1, Ohio

Please send me, without obligation, the following literature:

- ☐ Check Sheet of Water Line Requirements
- ☐ Facts on Prestressed Pipe
- ☐ Price Pipe for Pressure Sewer Lines

Name_____
Title_____
Organization_____
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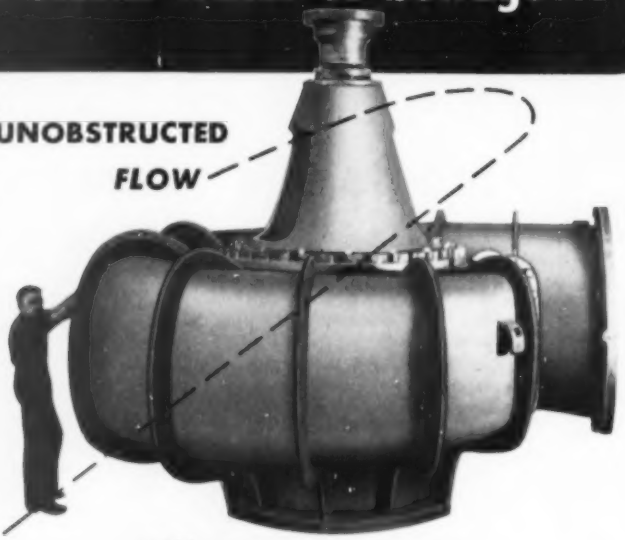
To handle LARGE Capacities of Storm Water or Sewage...

with UNOBSTRUCTED FLOW



—SPECIFY *Morris*

MIXED FLOW PUMPS

The most practical type of pump in the larger sizes, for abrasion resistance and ability to handle large stringy solids without clogging.

In the Morris Mixed Flow sewage pump there are no guide vanes in the suction, nor stationary diffusion vanes on the upstream side of the impeller, to catch longer fibrous material. Enclosed impellers which are most generally used are better able to withstand the abrasive action of grit and dirt. No internal bearings in contact with the sewage. Initial capacity and efficiency are maintained over longer period of time.

No other pump is so successful in maintaining freedom from clogging where large capacities and high speeds are required. In both vertical type (illustrated) and horizontal type, Morris Mixed Flow pumps have capacities ranging up to 150,000 G.P.M. In city after city, engineers prefer Morris pumps for efficiency, dependability, long life and economy. Every unit is backed by 84 years' experience in hydraulic engineering.

Write for your free copy of bulletin 178, describing Morris Mixed Flow Pumps.

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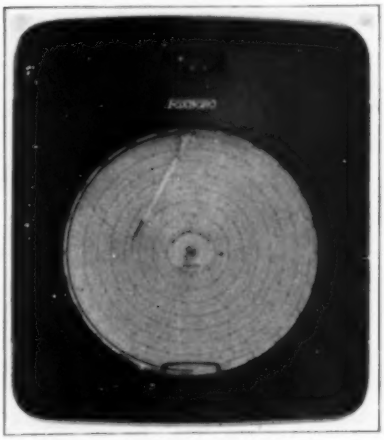
MORRIS *Centrifugal Pumps*

U. S. Movidyn Appoints Dr. Phillips Associate Director

United States Movidyn Corporation, Chicago, Ill., has announced that Dr. J. Neal Phillips, Jr., University of Texas biochemist, has been appointed associate director of research and development.

Dr. Phillips, a graduate of the University of Texas at Austin, served in both the Army Air Forces and the Navy during World War II, and has been a research scientist in cellular physiology and biochemistry at Texas for the last three years.



Controlled Solution Feeder Regulates pH, Concentration

501

Foxboro Company, Foxboro, Mass., has developed an instrumentation technique that makes possible improved processing through automatic control of chemical feeders. Designed for application to the Lapp Pulsafeeder Pump, the instrumentation permits the automatic feeding of treating chemicals either to maintain uniform concentrations or to correct variations of pH in any continuous process.

Operated by a constant speed electric motor, the Pulsafeeder Pump is

controlled through a pneumatic cylinder which varies the piston stroke length to change the feed rate. This cylinder is automatically positioned by a Foxboro Pneumatic Transmitter or a Foxboro Dynalog Controller, depending upon whether chemcials are to be proportioned to flow or added to control the pH of the fluid.

Since transmission and control are completely pneumatic, the system of automatic feeding offers maintenance economy, accuracy, and operating simplicity. Any number of supplementary indicators, recorders or controlled diaphragm feeders can be operated from one pneumatic signal, permitting unlimited combinations of information and control.

White Elected Vice-President of A. C. F.

American Car and Foundry Company, New York, N.Y., has announced that James M. White has been elected vice-president in charge of manufacturing for the Company.

Mr. White will have overall responsibility to determine and control manufacturing and related operations at all locations of the company. He will maintain headquarters at ACF's general offices at 30 Church Street, New York.

A native of Alabama and a mechanical engineer from Alabama Polytechnic Institute at Auburn, Mr. White went with Allis-Chalmers in Milwaukee upon graduation in 1929. He rose steadily in position from engineer to vice president in charge of manufacturing for all of A-C's plants, in which position he served from 1942 to 1948. In the latter year, he joined the Allen-Bradley Company as manufacturing executive, remaining there until joining ACF.

Split-Case Pump Line Consolidated

502

Peerless Pump Division, Food Machinery and Chemical Corporation, Los Angeles, Calif., has recently completed the modernization and consolidation of a complete line of 2, 3, 4 and 5-stage, split-case pumps.

Designated as its Type TU line, these pumps are offered in 2-stage designs with capacities up to 3,000 gpm and heads up to 800 feet and for liquid temperatures up to 300°F. Case pressures for the 2-stage pumps range from 300 to 400 lbs., and drivers of up to 325 bhp can be applied. The 2-stage designs are available in 1½"—8" discharge sizes. In discharge sizes up to and including 4" discharge, the

STEVENS

TYPE B-FT RECORDER PROVIDES PERMANENT DATA ON SEWAGE FLOW

At this modern sewage treatment plant in Dallas, Oregon, the STEVENS Type B-FT Recorder provides a permanent graphic record of flow in million gallons per day (range 0-6 MGD) and totalizes the volume in gallons. The STEVENS Recorder is mounted over a stilling well connected to a 9" throat width Parshall flume.

record flow accurately . . . automatically

There is good reason why modern municipal sewage and industrial waste measuring installations use the STEVENS Type B Recorder. It may be wall, pedestal or panel mounted, is easily operated and will give a lifetime of accurate, trouble-free service. This Recorder uses a circular chart which makes one revolution per day or per seven days, as specified, while the pen swings in an arc around an external center—the combined movements thereby producing a graph of the rate of flow (or head) against time. Volume is indicated on a counter-type totalizer. Accuracy of the registration is limited only by the accuracy of the rating to which the totalizer is set. Flow or head (or both) may be indicated on a scale clearly visible through a large glass port.

RECORDS FLOW
RECORDS HEAD
TOTALIZES FLOW
Direct Float Operated or Remotely Controlled

To find out more about the STEVENS Type B Recorder, and how it can simplify the task of compiling accurate flow records, write for FREE Bulletin 25.

SEND FOR NEW STEVENS DATA BOOK

Puts interpretive data at your finger tips. 144 pages of technical data . . . information on float wells and recorder installations . . . a wealth of hydraulic tables and conversion tables.

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ACTION *proves* **MARLOW PUMPS** *are the* **BEST** *. . . for dependable, low-cost performance!*

Again Marlow gets the job!*

23 Marlow Plunger Sludge Pumps Installed at the Southeast Sewage Treatment Plant, San Francisco, Calif. —*for re-circulation, draw-off and transfer of sludge.*

ONCE MORE—Marlow Pumps are relied on for dependable, low-cost performance. Already over 400 municipalities, across the country, have installed Marlows because they are efficient, reliable and durable. They are built for the hard jobs and give that extra "plus" when constant pump performance counts most.

At the Southeast Sewage Treatment Plant, Marlows do a complete job:

- **re-circulating sludge in digesters and transfer of sludge between digesters**
- **draw-off of sludge from digesters at a steady rate**
- **transfer of processed sludge from one elutriation tank to another**
- **transfer from final elutriation tank to vacuum filters**
- **transfer of raw sludge from thickening tanks to holding tanks or digesters.**
- **re-circulation of raw sludge in holding tanks or between holding tanks and receiving and thickening tanks.**

Marlow Plunger Sludge Pumps are the direct result of many years of "on-the-job" research and development. They have set the pace for design refinements to meet job specifications.

Available in simplex, duplex, triplex or quadruplex assembly. 360 to 30,000 GPH capacity.

Write for details today. 105

- Remember . . for pumping sludges or heavy industrial wastes Marlows do the job better because they are designed and built better. Marlow *means* good pumping.

MARLOW PUMPS RIDGEWOOD, NEW JERSEY
Branch Plant: De Queen, Arkansas
Other factories in France and England. Distributors and Dealers everywhere

crossover between stages is built integrally with top part of the pump case. In discharge sizes over 4", the high loop crossover between stages is used, extending over and above the top half of the pump case.

Beyond the 2-stage design, 3, 4 and 5-stage pumps are available in the TU line. 3-stage specifications provide head ranges to 950 feet and capacities up to 1400 gpm. 4-stage specifications provide head ranges to 1600 feet and capacities up to 900 gpm. 5-stage specifications provide head ranges to 1550 feet, and capacities up to 300 gpm. Liquid temperatures up to 300°F. can be handled by these three types.

Pennsalt Transfers Hampson, Staples

Pennsylvania Salt Manufacturing Company, Philadelphia, Pa., has announced that Philip C. Staples has been appointed Chicago District Sales Manager of the Industrial Chemicals Department. He replaces John C. Hampson, who returns to the Philadelphia office as a Product Supervisor in the same department.

Mr. Staples, a graduate of Harvard University, joined Pennsalt in 1937. After finishing the company's Student Training Course, he served in the company's Technical Service Department, Sales Development Department, Metal Processing Department, Industrial Chemicals Department, and most recently he has been Manager of Pennsalt's Washington office. During World War II he had an outstanding record as a Lieutenant Colonel in the Rangers in the United States Army under General Patton in the European Theatre.

Mr. Hampson, a graduate of the U. S. Naval Academy, joined Pennsalt in 1936 as a salesman in the Food Industries Department. He subsequently served in the Purchasing Department as an expediter and then returned to sales in Metal processing and Industrial Chemicals. He was Chicago District Sales Manager for two years before his recent appointment.

New Kjeldahl Flask

503

Fisher Scientific Company, Pittsburgh, Pa., has developed a new 500-ml Kjeldahl flask that makes possible rapid, genuinely streamlined Kjeldahl determinations.

Developed in conjunction with Dr. William Rieman III, of Rutgers, the new flask has a removable neck with a standard-taper joint at its base. This makes it possible to titrate right in the

bulb of the digestion flask and by removing the neck entirely and inserting a refluxing condenser with a standard taper joint, chemists can reflux prior to actual digestion.

H. Moretty

W. F. Haendel

Moretty Joins Neptune, Haendel to Wisconsin

Neptune Meter Company, New York, N.Y. announces that Henry Moretty has joined its sales force. He will represent the company in the sale of water meters in the State of Oregon, with headquarters at Portland.

Mr. Moretty is well known throughout the Pacific Northwest in the water works field, having been active in the Pacific Northwest Section of the American Water Works Association.

He comes to Neptune after seven years with the Parkrose Water District as Superintendent.

Mr. William F. Haendel will represent the company in the sale of water meters in the State of Wisconsin. Since 1933 he has been on the sales force in Chicago.

Mr. Haendel succeeds Mr. Francis Cunningham who retired from active company service on January 1, 1953.

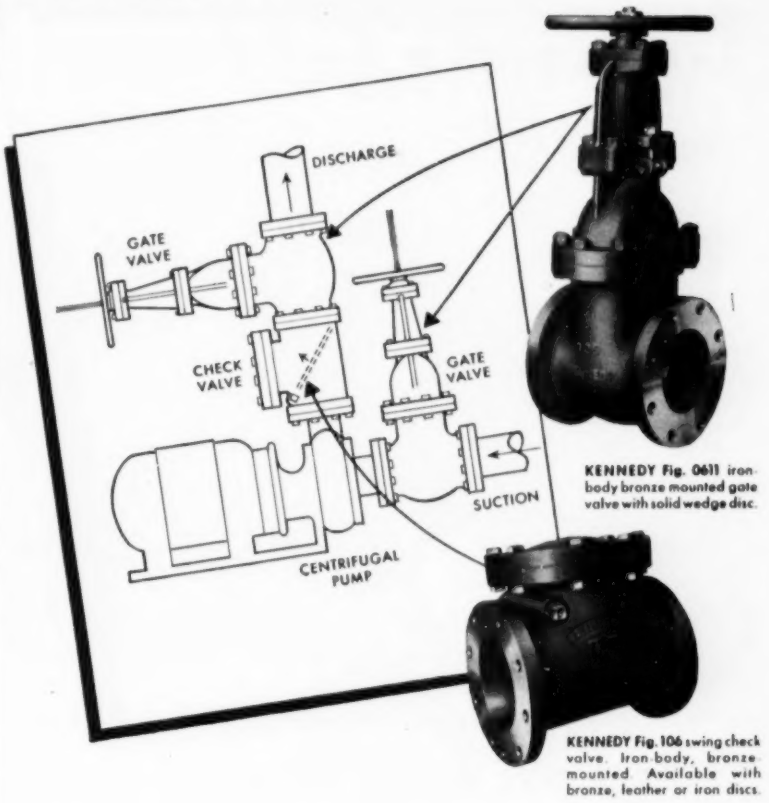
Indicating, Recording and Totalizing Meter

504

Simplex Valve and Meter Company, Philadelphia, Pa., has developed the Type H-Meter for the accurate measurement of water, gas, air, sewage, sludge or other industrial liquors. This mercury flow type indicating, recording and totalizing unit, operates in conjunction with Venturi tubes, flow nozzles and orifice plates. It is so calibrated so as to give a plus or minus 2% accuracy at any point, over flow ranges as wide as 13:1.

Insul-Mastic Appoints Southern Regional Manager

The Insul-Mastic Corporation of America, Pittsburgh, Pa., has named John C. Tyler as its Southern Regional Manager. Mr. Tyler will be located in the company's Houston



KENNEDY Fig. 0611 iron body bronze mounted gate valve with solid wedge disc.

KENNEDY Fig. 106 swing check valve. Iron body, bronze mounted. Available with bronze, leather or iron discs.

How proper valving assures easy maintenance of centrifugal pumping systems

In the diagram, you will note that there is a *gate* valve on either side of the pump.

On the suction side, it is connected directly with the pump. On the discharge side, the *swing check* valve should be located between the pump and the *gate* valve.

With this set-up, the flow can be readily shut off between the two gate valves to provide fast, easy repacking or other maintenance on the pump or check valve. And in a multiple pumping system, any one of the pumps can be shut down while the others continue to operate.

KENNEDY **JOB-FITTED** **iron-body gate and swing check valves** are ideally suited to this application. They are designed and constructed for heavy-duty service with water, oil, gas or any fluids that will not corrode bronze or iron. The rising stem on the KENNEDY outside screw and yoke gate valves tells whether valves are open or closed. KENNEDY swing check valves have readily removable cap for easy inspection or adjustment.

THE COMPLETE LINE OF KENNEDY JOB-FITTED valves and INSPECTED fittings is sold through local distributors, ready to give you fast and convenient service.

Est. 1877

THE **KENNEDY**

VALVE MFG. CO. • ELMIRA, N.Y.

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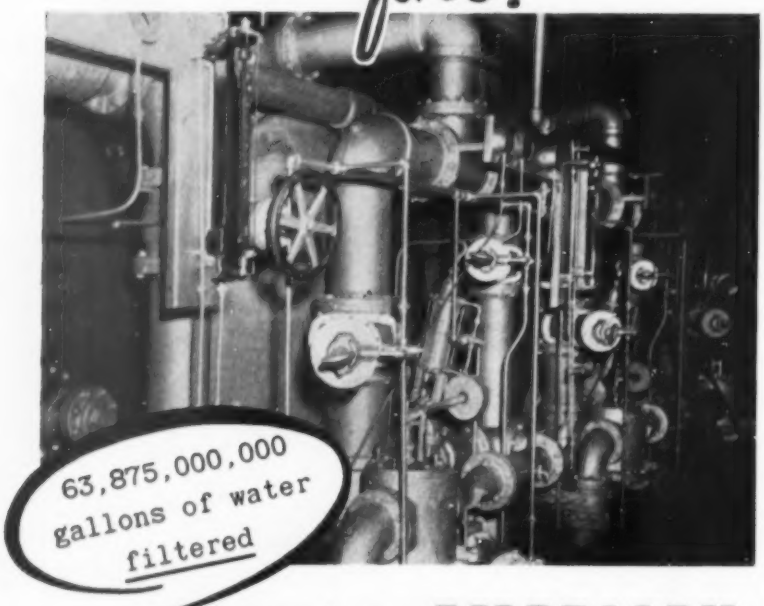


...through an AMERICAN
PRESSURE FILTER INSTALLATION
without replacing a single Filter Bed!

Largest pressure filter plant in the world still in operation!

AMERICAN installed the largest pressure filter plant in the world—26 horizontal units, 8' x 20'—at the United Piece Dye Works, Lodi, N.J., more than 25 years ago—and these units have been in continuous operation 24 hours a day ever since, filtering 7 million gallons a day from the muddy Saddle River *without having to replace the filtering material.*

Only the AMERICAN feature of adequate underdrain system for uniform collection of filtered water and proper distribution of backwash water made it possible for these pressure filters to perform so effectively for so long . . . Here is more than a quarter-century of proof *in action* that AMERICAN Pressure Filters outperform and outlast all others. They are designed and built to give you a clean, clear effluent for any industrial or domestic purpose for many, many years. Any number of filters can be manifolded to provide unlimited capacity. Available in both vertical and horizontal types in a wide range of sizes.

Call or write today for further information.

SERVICE SINCE 1902 TO THE INDUSTRY

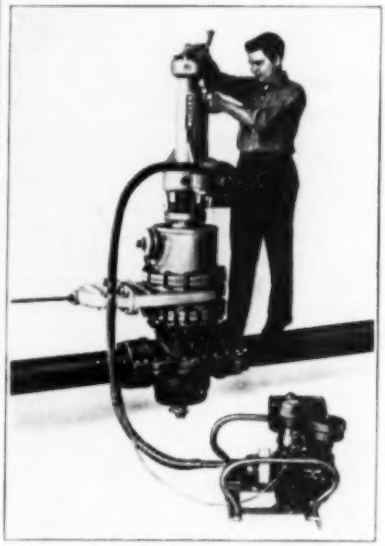
AMERICAN *Water Softener* COMPANY
INCORPORATED

FOURTH AND LEHIGH AVENUE • PHILADELPHIA 33, PENNSYLVANIA

DEAERATORS • HOT PROCESS SOFTENERS • REACTORS • FILTERS • ZEOLITE SOFTENERS • CHLORIDE DEALKALIZERS • AERATORS & DECARBONIZERS
HYDROGEN-SODIUM ZEOLITE SOFTENERS • DEMINERALIZERS • CHEMICAL FEEDERS • CONTINUOUS BLOWDOWN • SWIMMING POOL EQUIPMENT

office. From here he will travel throughout the south and the Gulf Coast area. He will provide sales and technical assistance to Insul-Mastic Licensees in this territory.

John Tyler was raised in the Texas oil country and at one time was engaged in geophysics and subsurface geology work for the Atlantic Refining Company. For the past eight and a half years, however, he has specialized in the sale of industrial paints and asphaltic coatings for the protection of refineries and chemical plants on the Gulf Coast.



Inserting Valves and Equipment

505

Mueller Co., Decatur, Illinois has recently developed 4", 6", and 8" inserting valves and equipment. With this equipment, these valves may be inserted under pressure with no loss of water in any existing line.

The Mueller H-800 inserting valve is especially designed for insulation in existing lines where additional valving is required and a shut-down of the line is impractical or hazardous. Once installed, the inserting valve may be closed at any time it is desirable to work on the section of line it controls.

Inserting valves are available in 4", 6", and 8" sizes. Sizes of valves correspond to the size of the main and all valves have full-size seat openings. The newly designed valve sleeve is smaller and permits faster, easier installation in a minimum space, thus saving both time and expense. The sleeve is constructed of heavy cast iron with asbestos composition packing between valve body and valve casing and lead gasket between halves of sleeve. Mechanism of the valves

is identical with that of standard Mueller A. W. W. A. gate valves, thus making repair parts for both interchangeable.

Any of several Mueller Drilling Machines may be used as the primary unit for drilling the main and inserting the valve plug. Mueller's CC, hand-operated, or C-1, power operated, machines with either 25" or 36" travel are suitable. Power units for use with the C-1 Drilling Machine are either the H-600 air motor or the new H-602 gasoline engine drive.

New Koehring District Representative

Koehring Company, Milwaukee, Wis., has announced the appointment of K. R. Chandler as District Representative for the Koehring Company and subsidiary companies, Parsons and Kwik-Mix in the territory comprised of Utah, Arizona, Nevada, and California.

Mr. Chandler joined the Koehring Engineering Department in 1948. He was transferred to the Sales Department in 1950 and has been active in sales since that time.

Chandler graduated from the University of Wisconsin in June 1947 with a degree in Civil Engineering. After graduation he remained at the University for a semester and served as an instructor in the School of Engineering.

Mr. Chandler will be working out of Stockton, California. His address is 1912 West Sonoma.

Low-Cost Sewer Cleaner

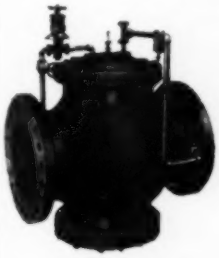
506

The Oster Manufacturing Company, Cleveland, Ohio is now marketing its completely new electric "Sewer Master."

PROTECT YOUR WATER SUPPLY
with
ROSS AUTOMATIC VALVES

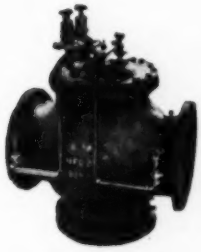
EFFICIENT REGULATION OF DISTRIBUTION PRESSURES IS A PROVEN METHOD OF CONSERVATION IN THE FIGHT AGAINST DIMINISHING WATER SUPPLIES

ROSS
1879



PRESSURE REDUCING VALVES

Maintains constant discharge pressure for all changes in rates of flow down stream.



COMBINATION PRESSURE REDUCING AND BACK-PRESSURE VALVE

BACK-PRESSURE VALVE

Maintains constant upstream pressure regardless of draft down stream.

OTHER ROSS PRODUCTS

ALTITUDE VALVES • FLOAT VALVES • RELIEF VALVES
HYDRAULIC BOOSTER PUMPS
STRAINERS AND SPECIALTIES

Write for Catalog #50

ROSS VALVE MANUFACTURING CO., INC.
4 OAKWOOD AVENUE——TROY, NEW YORK

GATE OPERATORS
—
PORTABLE
—
FOR STANDS & UNDERGROUND GATES—MOTOR TRUCK MOUNTED
PAYNE DEAN & CO.
CLINTON, CONN.

A powerful, low-cost machine, the new "Sewer Master" weighs less than 100 lbs. and will easily fit into the trunk of a car. It clears obstructions 100 feet or more from the sewer entrance. Four large rubber tired wheels and a two-position handle makes it easy to move up and down stairs and to the job.

In operation, cutting tools are attached to a coiled spring "snake" which is securely held and revolved at any convenient distance from the sewer entrance by the revolving chuck jaws of the "Sewer Master." These cutting tools efficiently remove roots, grease, chips, and other obstructions.

A snap switch reverses the powerful motor on the "Sewer Master" so the "snake" can be revolved in either direction. This assures easiest removal of toughest obstructions. Complete control of the "snake" action is maintained through the convenient control lever.

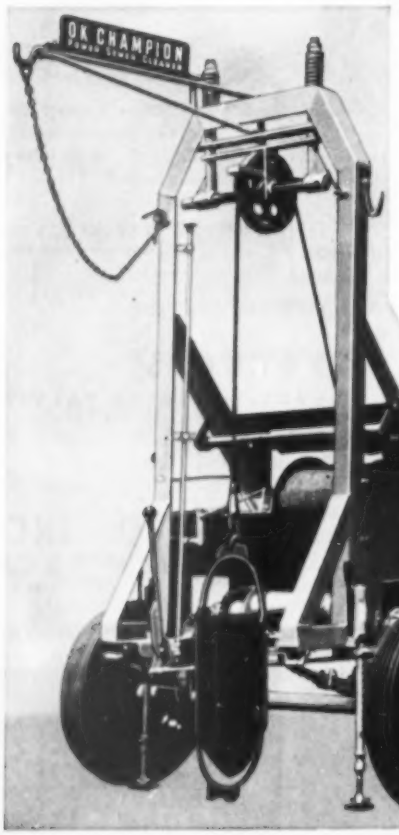
A. O. Smith Opens New Service Branch

A. O. Smith Corp., Milwaukee, Wis., has announced the opening at Oakland, Calif., of a new service branch of its Product Service Division.

The new Oakland branch is designed to provide a central, West Coast, location for efficient handling of replacement parts, service, repair and training operations.

Charles E. Smith, Product Service Division manager, has designated George A. Carlson as manager of the new Oakland branch. The Division, with headquarters at Chicago, has other service plants at Union, N. J. and Dallas, Tex.

OK CHAMPION
Power Sewer Cleaners



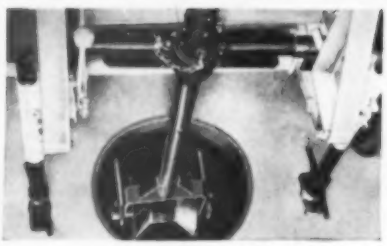
Mounted on Compact, Perfectly Balanced Four Wheel Trucks—for safety—to eliminate lifting in positioning over or pulling away from manholes—for safe tandem towing.

All Controls Grouped at Working End—keeps operator out of passing traffic—gives him full vision of operations.

Built-in Gear Reduction Ratio Engineered for Each Model—utilizes engine power and speed for correct bucket travel speed and pulling power ratio.

Equipped with Slower Operating Engines—air or water cooled—for long life, operating economy.

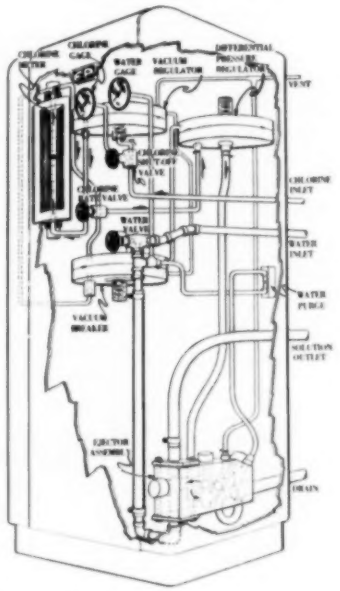
Fully Automatic Safety Clutch—instant acting—avoids damage to tiles and machines.



Pole Suspended Guide Wheel—a new O K Champion feature—lowers from street level—keeps men out of manhole. Fits any model O K Champion Power Sewer Cleaner Truck.

Write for latest O K Champion Circular.

CHAMPION CORPORATION
4700 Sheffield Avenue
Hammond, Indiana



Corrosion-Resistant, Chlorine Dispenser

507

Fischer & Porter Company, Hatboro, Pa., has developed a new vacuum-type solution-feed chlorine dispenser, including new corrosion-resistant materials unaffected by either dry or wet chlorine gas. The dispenser has either manual or automatic proportioning control in capacity ranges up to 1000 PPD maximum. Large diaphragm areas in the regulators and minimum friction in the few moving parts assure constant chlorine flow rate in the manual-reset model and accurate ratioing in the automatic proportioning dispenser. Since chlorine flow rate is changed by a simple valve setting while the vacuum is held constant, the dispenser may be readily adapted for remote setting with an air-operated diaphragm motor valve.

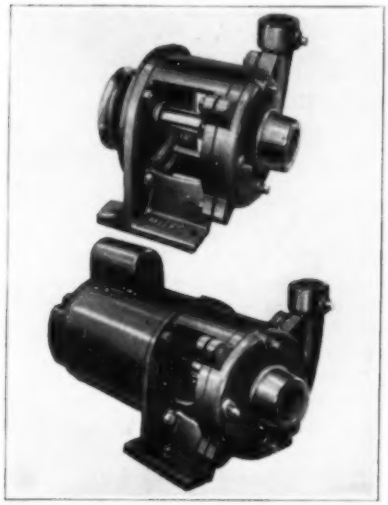
Although in normal operation the chlorine remains completely dry until the regulated flow of gas enters the water stream at the injector, after which the chlorine-water solution immediately leaves the system, the new chlorine dispenser will be unaffected should water vapor enter the chlorine

lines. Materials used to insure no internal corrosion include Uscolite, Teflon, Kel-F, Hastelloy "C", Monel, silver and tantalum.

Advertising Manager Appointed by Inertol

Inertol Co., Inc., Newark, New Jersey, has announced the appointment of James A. Condon as Manager of Advertising and Technical Services.

Mr. Condon has been in charge of correspondence and customer contact in Inertol's Technical Service Department for seven years. He has functioned as liason between customers and Inertol factory, giving special attention to difficult painting problems.



Low Price Centrifugal Pump Line

508

F. E. Myers & Bro., Ashland, Ohio, has introduced Centri-thrift, a competitive priced line of centrifugal pumps.

Manufactured in ⅓, ½, ¾ and one horsepower sizes, and powered by a 3450 R.P.M. capacitator-type motor with built-in overload protection, the new Myers pump line will develop heads up to 92 feet with capacities up to 50 gallons per minute.

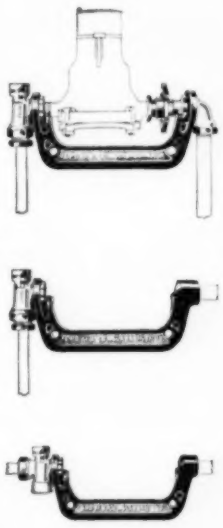
Designed for high efficiency, the pump features a corrosion-resistant stainless steel pump shaft, a removable bronze wearing ring and a rotary seal which eliminates the usual "packing-box drip." All parts are easy to replace.

Cuneo, Leslie Promoted by Fairbanks-Morse

Fairbanks-Morse & Co., Chicago, Ill., has announced that at the annual meeting of stockholders, J. A. Cuneo,

a Ford Yoke

for EVERY SETTING



Ford Yokes are made in styles to meet every meter setting condition—indoors or out. Regardless of location, the Ford Yoke makes settings easier, removes pipe strains, saves labor and keeps meter connections permanently aligned for fast changes. Roughly, Ford Yokes are made in three styles:

1. Riser Yokes, to use where the meter must be raised above the service line.
2. Angle Yokes, to satisfy a vertical inlet, horizontal outlet condition.
3. Straight Line Yokes, for setting meters in a horizontal line without raising the level of the meter.

Every Ford Yoke is permanently satisfactory. Send for full information.

FOR BETTER WATER SERVICES **FORD**

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

WATER SUPERINTENDENTS

Consider the Advantages of Pollard L-P Gas Burner Furnaces

Burns L.P Gas (commonly known as "Bottled Gas"). Thoroughly tested and proven. Melts approximately 50 lbs. of lead in 9 minutes. Flame can be adjusted to maintain desired temperature. One cylinder of gas will operate unit for many hours.

CyEnders are made of armor plate.

Catalog No. 25 C.P. on Request

JOSEPH G. POLLARD CO., Inc.

PIPE LINE EQUIPMENT

New Hyde Park, N. Y.

General Sales Manager of the Company, was elected to the Board of Directors.

At the subsequent meeting of the Board of Directors, Orren S. Leslie was elected Vice President in charge of Manufacturing, and G. J. Malone, formerly Controller, was elected Vice President - Controller. Mr. Leslie joined the Fairbanks-Morse Company in 1951 as Works Manager of the Beloit, Wisconsin, plant. A year later he was appointed Manager of Manufacturing.

Mr. Malone has been with the Company many years and has progressed from the ranks to his present position.

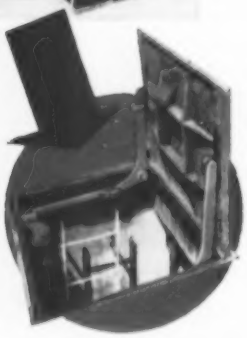
J. A. Cuneo has been with the Fairbanks-Morse organization since 1929. Starting as a foreign traveling representative, he held many positions successfully. In 1947 he was appointed Manager of the Company's Los Angeles Branch, and in 1949 he became Manager of their Chicago Branch. For the past two years he has been General Sales Manager.

Darling Valve Opens New York Office

Darling Valve & Manufacturing Co., Williamsport, Pa., has announced the opening of a new sales office at 500 Fifth Avenue, New York 36, New York. The telephone number of the new Office is CHickering 4-6017.

WACHS Safety Vault Covers

for Valve, Meter, Transformer and District Governor Vaults



Features

- One man can quickly raise cover with ease and without danger.
- Cover can not drop into vault or slam to cause injury or damage.
- Cover can be opened from the inside of the vault by one man—an added safety feature.
- Positive tamper proof lock that cannot be opened unless key is used.
- Open cover stands in upright position indicating that manhole is open.
- Unobstructed 30" square opening gives ample room for installation and servicing heavy equipment.
- Heavy duty for heavy traffic—cast iron frame and ribbed steel cover both machined for accurate fit to eliminate rattle.
- Moisture resistant, heavy cast steel levers and linkage with stainless steel pins in "Oilite" permanent oiled bronze bushings for long trouble-free service.
- Complete counterbalance structure protrudes less than 6" from the wall.

WACHS NATIONAL PIPE SAWS

Make Fast and Accurate Cuts on 10" to 48" Cast Iron and Steel Mains

16" clearance between 24" mains

Features

- Minimum Pipe Line down time.
- Cuts under water in flooded ditches.
- No broken pipe, milled cut.
- Thor Air-Powered, no flames near pipe.
- Set-up time about 15 minutes.
- Portable — weighs only 315 lbs. Two men can carry and set up unit.
- Small excavation—only 16" clearance needed.
- One machine cuts all pipe sizes from 10" to 48".
- Only two adjustments necessary for size changes.
- Cuts 24" pipe in 24 minutes — 36" pipe in 36 minutes, etc.

Write today for descriptive folder and engineering data on this new labor saving saw.

THE E. H. WACHS COMPANY

Manufacturers of Engineers, Valves and Machinery since 1893

1525 NORTH DAYTON STREET · CHICAGO 22, ILLINOIS

Triple Hand Tamper

509

Le Roi Cleveland, Rock Drill Division, Cleveland, Ohio has developed the TT11 Triple Hand Tamper that consists of three standard No. 11 Back Fill Tampers assembled to a common head. In their common head, the air control valve is incorporated which is easily accessible to the operator.

Swivel air inlet is provided for operator's convenience to keep air hose away from ground.

This one man tamper can replace five hand-operated tampers which means a saving of man-hours, plus air compressor service and fuel consumption.

Long handle bars keep operator away from Tamper to avoid injury.

Permutit Promotes Durando Miller, Jr.

The Permutit Company, New York, N.Y., has announced the promotion of Durando Miller, Jr., to the position of Assistant Technical Manager, reporting directly to H. L. Beohner, Vice President. He joined Permutit in 1938 as a member of the sales estimating department and was

transferred in 1941 to the technical department, serving there until his new appointment.

Mr. Miller graduated from the Yale School of Engineering, receiving a Bachelor's degree in Civil Engineering in 1938. He has written a number of papers on the various aspects of Sanitary Engineering and served for three years as an instructor of Industrial Water Treatment to classes in Sanitary Engineering at the Graduate School of Engineering, New York University.

Torex, Chemical Resistant Enamel

510

Inertol Co., Inc., Newark, New Jersey, has developed Torex, a chlorinated rubber enamel that protects masonry, metal and wood surfaces against the corrosive action of severe chemicals and water even on submerged surfaces.

The company reports that field tests of Torex enamels were made as early as 1935 in paper plants, and this early field testing under the corrosive conditions of acids, alkalies, bleach solutions, chlorine gas and high humidity, formed the basis for its use in many other industries such as breweries, bottling plants, dairies, packing plants, canneries, petroleum and chemical industries and public water works.

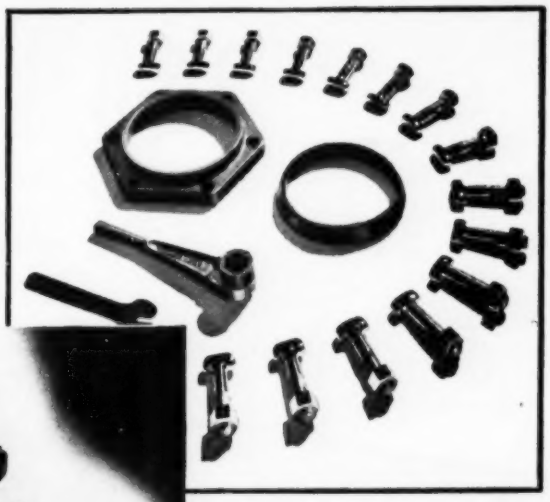
MacNamara Joins Beckman as Field Sales Manager

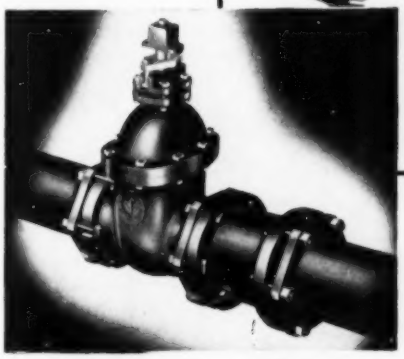
Beckman Instruments Inc., South Pasadena, California, has announced that John D. MacNamara has been named Field Sales Manager.

His appointment follows a recent enlargement of the company's national field staff to further assist users and distributors of Beckman analytical and control equipment. MacNamara initially will oversee the training of 20 new field engineers and will coordinate their activities to provide maximum service for research and process industries over the country.

The Philadelphia-born engineer graduated from Villanova College in 1941 and spent the next four years with the General Electric Company, Lynn, Massachusetts.

ALL YOU NEED





IS: A RATCHET AND OPEN END WRENCH, THREE RUBBER GASKETS, THREE CAST IRON FOLLOWER RINGS AND A HAND FULL OF BOLTS AND NUTS TO INSTALL

the New SMITH CUT IN VALVE & SLEEVE

Gone are the days of—large costly excavations—melting furnaces and pouring pots—pouring and caulking lead joints—when the New All Mechanical Joint Smith Cut In Valve and Sleeve is used.

The Cut In Valve can be installed rapidly, in fair or stormy weather on Cast Iron A.W.W.A. and Federal specification water mains, by unskilled labor, using only two wrenches.

Moulded rubber gaskets fit into machined "Stuffing Box" type joints, guaranteeing a permanent leak-proof seal.

Smith Cut In Valves are manufactured in compliance with the A.W.W.A. Gate Valve specification, and all parts are interchangeable with like parts of Smith A.W.W.A. Gate Valves.

Write for Bulletin No. MJ2. 37

THE A.P. SMITH MFG. CO.
EAST ORANGE, NEW JERSEY

ANTHRAFILT
Trade Mark Reg. U. S. Patent Office
A Filter Medium For All Purposes

ANTHRACITE EQUIPMENT CORP.
Anthracite Institute Building
Wilkes-Barre, Pa.

All correspondence regarding sales and engineering should be addressed to:

PALMER FILTER EQUIPMENT CO.
822 E. 8th St. Erie, Pa.
Engineers and Sales Agents

BELL JOINT LEAK CLAMPS
GASKET SEALER COMPOUND
CHARCOAL CAST IRON BOLTS

Also Anchored Glands for mechanical joints to replace socket clamps.

Write for information

H. Y. CARSON COMPANY
1221 Pinson St. Birmingham, Ala.

In 1946, MacNamara joined the Industrial Division of the Minneapolis-Honeywell Regulator Company, where he last served as textile industry sales manager.

New Vinyl Primer Requires No Preparation

511

U. S. Stoneware Co., Akron, Ohio, has announced the availability of a new vinyl primer, "Tygorust," specifically developed for use on rusted steel surfaces without the necessity for previous preparation.

According to the company, Tygorust is easily applied by brushing, spraying or dipping; dries hard and can be overcoated in a matter of minutes; adheres tenaciously to rusted steel, damp or dry; and, can be used with any type of finish coating—particularly vinyls.

The company states that under exaggerated test conditions, Tygorust has been brushed and sprayed on damp rusted panels, and also brushed on dripping wet rusted panels, with completely satisfactory results. Dry, rusted steel has been successfully primed without even wire-brushing.

FLEXIBLE
PIPE CLEANING COMPANY
Cleans clogged mains for about
1/30 the cost of replacement!
Guarantees 95% new main
efficiency!
1 2 3 4 5 6 7 8 9 10 11 12 13

Clogged underground mains are terrifically expensive to own or operate! Every particle of scale and rust deposit cuts capacity, skyrockets your pumping and operating costs.

Now, you don't need to replace clogged mains. Flexible Pipe Cleaning Company can *clean* that stuffed up main—return it to guaranteed 95% efficiency—and AT A FRACTION OF REPLACEMENT COST. For example, new 10" steel line, 30" underground costs at least $6.00 a foot wrapped and laid. Tees and crosses are extra. Flexible can *clean* that SAME LINE FOR ABOUT 18¢ PER FOOT *—or 1/30th the cost of replacement!*

How much to clean your clogged mains? Send for our Preliminary Job Cost Estimate form. Take five minutes to complete this form and return it to us. We'll give you a free estimate on the cost of cleaning your pipe—stacked, stored or underground.

Our crews are near you, so write today for our preliminary job cost estimate form.

f-l-e-x-i-b-l-e
pipe cleaning company

9324 So. Norwalk Blvd. Los Nietos, California P.O. Box 167 OXford 5-5713

Siems Named Asst. Sales Mgr. of Philadelphia Quartz

Philadelphia Quartz Company, Philadelphia, Pa., has announced the appointment of Norman E. Siems as Assistant Sales Manager. Mr. Siems has specialized in water and paper uses of the silicates and has been in charge of the company's sales through distributors.

Mr. Siems was graduated from the University of Rochester, New York, with a B.S. degree in chemistry. He joined the Philadelphia Quartz Company in 1941 as a sales representative operating first in New York and later in the Middle West. In 1946 he was transferred to Philadelphia.

Centrifugal Sand Pumps

512

Denver Equipment Co., has available the Denver Vertical Centrifugal Sand Pump that handles frothy pulps without dilution or continuous operating attention.

According to the company, the important features that permit this pump to handle troublesome pulps are the facts that the feed pulp flows by gravity into the pump bowl; the vertical design overcomes stalling, plugging of pump, airlocking and surging; less floor space is required; the motor is mounted out of the reach of water and dirt and it is portable.

Denver Vertical Centrifugal Sand pumps are available in six sizes—¾", 1", 1½", 2", 3" and 4" sizes, providing a wide range of capacities.

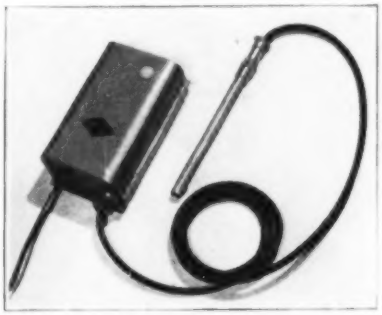
Haller Named Beckman Eastern Sales Manager

Beckman Instruments, Inc., South Pasadena, Calif., has announced the appointment of Dr. Elden D. Haller, senior sales engineer as Eastern Sales Manager.

Headquartered in a new Washington, D. C. office, Haller will supply a direct factory contact for Beckman district representatives and the scientific apparatus and recorder-controller firms which distribute Beckman products east of the Mississippi.

Haller holds a doctor's degree in chemical engineering from Ohio State

University. Before joining Beckman in 1942, he was chief chemist at the National Lime and Stone Company, Findlay, Ohio, and technical editor with the Ordnance section of the War Department.



Electronic Liquid Level Control

513

Thermo Instruments Co., Belmont, Calif., has developed a new Belmont Level Control that provides adjustment of liquid level and cut-in, cut-out differential over very wide limits. The new level control is based on the capacitive action of liquid surrounding a porcelain-enamel-covered electrode.

In operation, the new unit consists of the probe which is mounted directly at the location of the controlled liquid; a connecting cable which can be 1000 feet long if necessary; and the control unit which can thus be located for operating convenience. The two main controls (liquid level and differential) are designed for screwdriver adjustment while a vernier or fine control on liquid level is operated by a panel-front knob.

Standard models operate from 115-volt 60 cps supply while special units are available for 230-volt or 25 cps operation. The snap-action relay included in the unit is rated for 1-amp at 115 and 230 volts. An indicator light in the panel front indicates operation of the relay—burning at full brilliance when the relay is open, at half brilliance when the relay is closed.

The differential range varies with the type of service but, as an example, for ammonia control the standard unit operates between approximately 1 in. and 5 in. Wider ranges can be supplied with special units.

Beane Appointed Vice President at Bristol

Bristol Company, Waterbury, Conn., has announced the appointment of Harry E. Beane as Vice President of Sales.

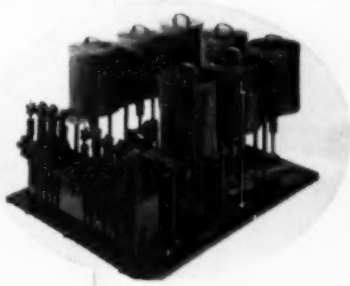
Mr. Beane joined the Bristol sales engineering organization in 1920 and in 1925 was appointed district man-

UTMOST PROTECTION

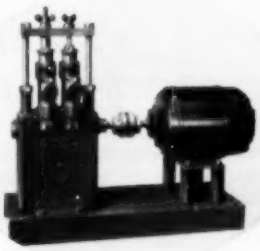
at lowest cost

Manzel CHEMICAL FEEDERS and HYPOCHLORINATORS

To the cost-conscious water and sewage treatment plant Manzel Feeders pay dividends in accuracy, dependability, and *surprising* economy of purchase and maintenance. Built by an organization famous for fifty years in the manufacture of automatic force feeding equipment, Manzel design is *thoroughly* proven. Whatever your feeding problem, ask Manzel.

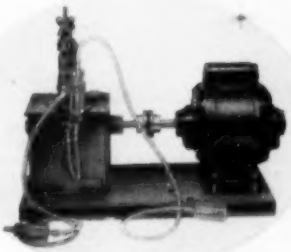


MULTI-FEED CHEMICAL FEEDERS
Any number of pumping units can feed the same or different chemicals simultaneously.



LARGE OR SMALL CAPACITIES
Various models pump from a fraction of a drop to 60 gph. All types of drives are available.

MANZEL HYPOCHLORINATORS
Positive, precise, and *low cost.* Easy to install and service.



Look at these Quality Features

- **Full control**... *accurate adjustment from 0 to full feed.*
- **Wide range** *of feed covers nearly every job.*
- **Positive in action**... *no clogging.*
- **Sight Feed** *and solution strainer.*
- **Easily adjusted** *while running.*

Manzel

3 Babcock Street, Buffalo 15, N. Y.

ager of the company's Birmingham, Ala., office. In 1930 he became district manager of the Pittsburgh district.

In 1943 he was made sales manager of the Instrument Division of the Company and in 1947 promoted to the position of general sales manager.

New Firm of Consulting Engineers

Preload Engineers Inc., newly-established firm of consulting engineers in prestressed design, announce the opening of their offices at 955 North Monroe Street, Arlington, Virginia.

This new firm, formed out of the Preload Company, Inc., was established to provide an organization concerned solely with the design of prestressed structures such as buildings, bridges, tanks, pipelines and pavements.

The firm will advise its clients on the suitability, practicability and availability of the various materials used for prestressing as well as any specialized construction procedures which may be involved.

The services offered by Preload Engineers Inc., include preliminary inspection and reports; preparation of detailed plans and specifications for construction; estimates of quantities and costs; analysis of bids and assistance in letting contracts; inspection, consultation and advice during construction.

Senior members of the new firm are Curzon Dobell, E. H. Thwaits, Cedric C. Stainer and Eric Molke.

Circular Collectors

Types for every waste treatment problem

- DESIGNED FOR EFFICIENT LONG-TERM OPERATION
- ENGINEERED FOR USE IN CIRCULAR OR SQUARE TANKS
- SELECTION OF DRIVES TO MEET YOUR SPECIFICATIONS
- CLARIFLOW THICKENERS FOR FLUE DUST CLARIFICATION

TRACTOR DRIVE COLLECTOR

This pier-supported collector is designed for circular tanks. The rotating bridge acts as the lever arm rotating a sturdy center cage which carries the collector arms. Rotational force is provided by a two-wheeled, rubber tired tractor unit running on the rim (or effluent weir wall of the tank). Drive unit is simple, easily accessible, and not affected by snow or ice.

SUSPENDED COLLECTORS are used where a simple bridge can span the tank diameter. In this case, the complete motor and drive assembly, together with the drive tube and collector arms, are suspended from the bridge.

WRITE FOR BULLETIN 9W65

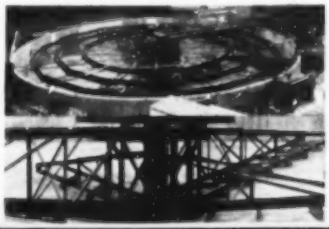
PIER DRIVE COLLECTOR

The Pier Drive Collector is recommended where it is undesirable to operate a Tractor Drive . . . where the access bridge must be stationary, or the corners of square tanks must be scraped. Center drive mechanisms, ranging from 1/2 to 10 horsepower, are built for long life and heavy duty service. Worms are carburized and ground steel and precision meshed with hardened bronze worm wheels. The balls run in hardened, ground, renewable ball races.

CLARIFLOW THICKENER

This unit utilizes the principles of fluid mechanics, so highly developed in Walker sedimentation units. It removes all settleable solids and remarkably clarifies the flow. All parts are sturdily built . . . designed for the "tough" jobs.

WRITE FOR BULLETIN 10169



PROQUIP PROCESS EQUIPMENT | WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA, ILLINOIS

Double-Ribbed V-Belt for Variable Speed Motors

514

U.S. Electrical Motors, Inc., Los Angeles, Calif., has developed a double-ribbed V-belt for use with variable speed motors.

The company stated that by application of the double-ribbed design, replacing the single-ribbed belt used for many years, greater speeds and smaller diameters can be combined. This in turn has permitted further design changes to develop greater horse-power within a smaller space than ever before. The result is maximum motor compactness. This newest of belt features, which provides double corrugation, reduces internal friction and permits greater flexibility without sacrifice of strength. The outer periphery is relieved of destructive tensile strains; the inner periphery is free from excess compression. The belt bends as easily as your finger.

Rockwell Opens Atlanta Branch

Rockwell Manufacturing Company, Pittsburgh, Pa., recently opened a new office, warehouse and service building at 1495 Northside Drive, N.W., Atlanta, Georgia.

In the warehouse will be carried complete stocks of standard Rockwell gas, water and oil meters, gas regulators, Nordstrom valves and repair parts. A maintenance department has been established to provide immediate repair work on Rockwell products, thereby saving customers freight charges to and from the factory.

J. W. Northcutt, Southern Regional Sales Manager and R. A. Johnson, newly appointed District Sales Manager, will headquarter at this new location from where they will direct the Sales activities for the entire Southeastern District.

Plastic Coated Work Gloves

515

Granet Corporation, Framingham, Mass., has developed a tough, colorful, new plastic-coated work glove to safeguard the hands of workers who do dirty jobs and handle harsh materials. Called Dynagluvs, the new product is completely liquidproof and highly resistant to abrasion and abuse. A seamless wing thumb provides an extra safety feature while a natural molded curve contributes to comfort.

Available in an attractive satin-finished emerald green, the plastic coating for Dynagluvs was developed in the manufacturer's own laboratories by chemists long familiar with plastic formulations. Dynagluvs are made in Knitwrist, Band Top and Gauntlet styles, either fully coated or palm coated. Each style is designed to fill a special need in industry.

Pennsalt Names Clem Gen. Sales Manager

Pennsylvania Salt Manufacturing Co., Philadelphia, Pa. has announced that Albert H. Clem has been appointed General Sales Manager, filling the position left vacant by the recent death of Russell S. Roeller.

Before this appointment, Mr. Clem was Assistant General Sales Manager. He joined Pennsalt in 1938 following his graduation from the Pennsylvania State College with the degree of Bachelor of Science in Chemical Engineering.

Starting in the Development Department of the Research and Development Division, he was subsequently a technical sales representative in the Detroit area for the Metal Processing Department; and then, in the same department in Philadelphia, a Product Supervisor, Assistant Sales Manager, and Sales Manager.

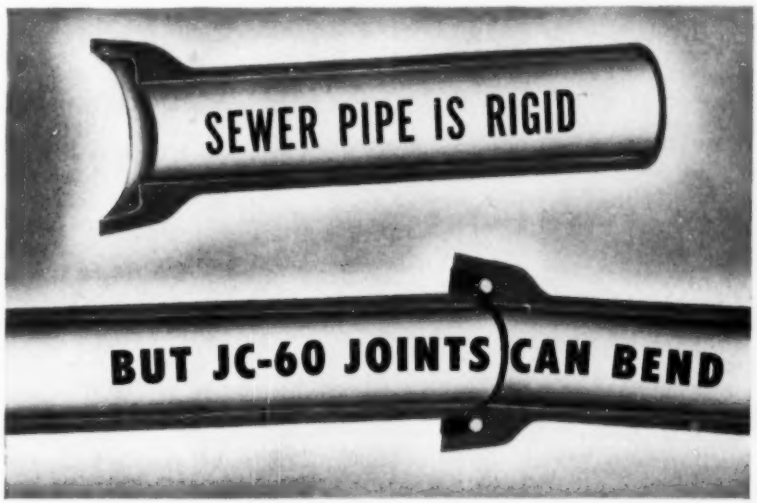
He then became Assistant to the Vice President in charge of Sales; Sales Manager of the Industrial Chemicals Department, and Field Sales Manager in Charge of all district sales offices.

Super-Resistant Floor Surface

516

Flexrock Co., Philadelphia, Pa., has developed a floor finish called AWOG, that is resistant to such common floor disintegrators as acid, water, oil, grease and is reported to outlast ordinary concrete by 3 to 1.

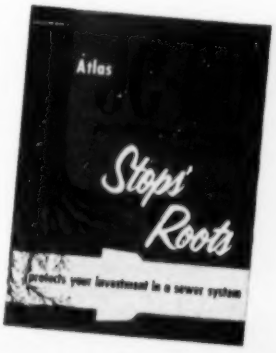
The extreme durability of AWOG is attributed to its tight, close-knit composition. Unlike concrete, liquids can't penetrate to attack the bonding element. Used for repairing broken areas or for complete overlays, AWOG sets up a smooth, case-hardened, dustless surface.



Joints poured with ATLAS JC-60® are stronger than the sewer pipe itself, yet flexible enough to withstand normal settling. Even on low temperature deflection tests, JC-60 joints have taken a 15° bend without *any* rupture of the leakproof bond. Compare these assuring results with other jointing compounds. Notice that the JC-60 compound holds . . . while others may fail.

Advantages of JC-60 such as positive resistance to root penetration, flexibility and others save you money . . . both in negligible maintenance and minimum pumping costs throughout years of service.

Get the complete facts.
Write for your copy of new Bulletin M20-3.

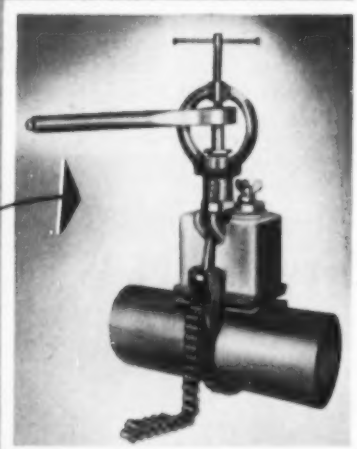


ATLAS MINERAL PRODUCTS COMPANY MERTZTOWN PENNSYLVANIA HOUSTON 1, TEXAS

ATLAS JOINTING COMPOUNDS
...a permanent bond

● If interested in equipment or literature mentioned below, mail a Reader Service Card with your name, address, and item key number.

It's new... and better!



the WELSBACH Kitson

CORPORATION TAPPING MACHINE

For installing corporation stops under pressure, this is the safest, surest, most easily-handled and, without sacrifice of inherent strength, the lightest corporation tapping machine ever made. It is so compact that it is ideal for making taps where space is limited.

It is the new Welsbach-*Kitson* Corporation Tapping Machine—an improved model of the popular Smith-Shelly Tapping Machine, equipped now with a flat chain and adaptor that provides positive non-slip pipe-gripping action . . . which makes it an even better machine than before. And in keeping with the simplicity of operation of this popular machine, the new adapter, which gives *positive* pipe-gripping action, is easy to set and helps speed the operation.

with the new POSITIVE, NON-SLIP PIPE-GRIPPING ACTION!

THE WELSBACH CORPORATION

Kitson Valve Division

1500 Walnut Street, Philadelphia 2, Pa.

Ellis Elected Director of Combustion Engineering

Combustion Engineering—Superheating, Inc., New York has announced the election of George D. Ellis, vice president and controller, as a director.

Mr. Ellis has been with the company since 1915 and, prior to his election as vice president in 1948, he successively was auditor, controller and secretary and controller. He is also a vice president and director of The Superheater Company, Ltd., Canada.

New Post for De Laval Sales Manager

De Laval Steam Turbine Co., Trenton, N.J., has announced that William J. Healy, sales manager of the De Laval turbine division, has been appointed to the additional post of sales manager for the blower and compressor division.

Mr. Healy joined De Laval in 1928, serving as a sales engineer for the Turbine Equipment Co., De Laval representatives in New England. In 1938 he transferred to the De Laval plant sales staff, handling steam turbines, gears, compressors, blowers and pumps. In 1950 he was appointed head of turbine sales.

Easy to Install Manhole Cushions

517

Joseph G. Pollard Co., Inc., New Hyde Park, N.Y., has announced the manufacture and distribution of TAPAX Manhole cushion.

The manhole cushion is a resilient non-adhesive cushion that acts as a seat for the cover, takes up the wear and controls the rotary motion of the cover. Tapax is composed of long fibre asbestos and an interweaving of bronze wire mesh and is processed to permit conforming to the irregularities of both the frame and cover.

Tapax is simple to install because an adhesive compound built into Tapax binds it to the seating flange of the manhole frame.

New Firm Formed

Calcinator Corp. to Manufacture Automatic Garbage Disposal Unit

The newly formed Calcinator Corporation, Bay City, Michigan, manufacturer of the Calcinator automatic garbage disposal unit, has announced two major appointments to its staff. The Calcinator Corporation until early this year was a division of the Valley Welding & Boiler Company, Bay City, Michigan. Calcinator Corp. manufactures an electrically operated home incinerator.

George H. Kennedy, until recently associated with the Consumers Power Company of Michigan, has been appointed assistant to Willard M. Milbourne, sales manager.

Hardy B. Payor has been appointed Director of Marketing for the corporation. Mr. Payor will be directly concerned with the rapidly growing market for the electric model Calcinator. Until his appointment he served as a vice-president of Landers, Frary & Clark, New Britain, Connecticut.

Duplex Laboratory Heater

518

Labline, Inc., Chicago, Ill., has developed a new Speedi-Heet Duplex Heater for laboratory heating operations.

The heater contains a new reflector type heating element that eliminates lower refractory. It has a nickel rod core and Nichrome heating coils that develops maximum heat in 15 seconds, and cools to black heat in 7 seconds. The case is cast aluminum with a hammerloid finish and is well ventilated to remain cool at all times. A removable support rod provides an easy method of mounting apparatus on the heater, or fastening the heater to a setup frame.

The heater is available in three types:

1. Powerstat controlled, with one 350 watt element controlled by on-off switch; the second 350 watt element controlled by Powerstat transformer. This model provides stepless control from 0 to 700 watts.
2. Rheostat controlled. Duplex heating element has 200 watts controlled by on-off switch and 350 watts on rheostat which also has an off position. The rheostat controls 150 to 350 watts, giving a full range from 150 to 550 watts without overloading.
3. Single heat, 700 watts.

Naylor Joins Koppers Division; MacArthur Heads Washington Office

Koppers Co., Pittsburgh, Pa., has announced the appointment of George W. Naylor, head of the Washington, D.C. office, for the past two years, as Assistant Vice President and Assistant Sales Manager for the Tar Products Division of the Company.

Simultaneously, it was announced that Donald MacArthur, who has been Assistant Manager of the Central Staff Sales Department of Koppers, will become the new Manager of the Company's Washington office.

Mr. Naylor, a native of Stamford, Conn. and graduate of Cornell University with a degree in chemistry, will assist J. C. Macon, Jr., Sales Manager of the Division.

He joined Koppers in December 1948 as Manager, Development Section, of the Company's Chemical Division. In April, 1951, he was named Manager of the Company's Washington office.

Mr. MacArthur joined Koppers as a cadet engineer after graduation

M&H BOOTH

A. W. W. A. CONVENTION EXHIBIT

GRAND RAPIDS AUDITORIUM—MAY 10-15, 1953

We hope to see you at the big show in Grand Rapids. Come by our M & H Booth in the Exhibit Hall. Whether you feel like sounding a barbershop chord, or talking valves and hydrants, or just resting your tired "dogs"—you'll be quite welcome. Incidentally, in case you're interested, we'll have a nice display of M & H products.

M & H Valve and Fittings Company, Anniston, Alabama

M&H PRODUCTS FOR WATER WORKS • FILTER PLANTS INDUSTRY • SEWAGE DISPOSAL AND FIRE PROTECTION

● If interested in equipment or literature mentioned below, mail a Reader Service Card with your name, address, and item key number.

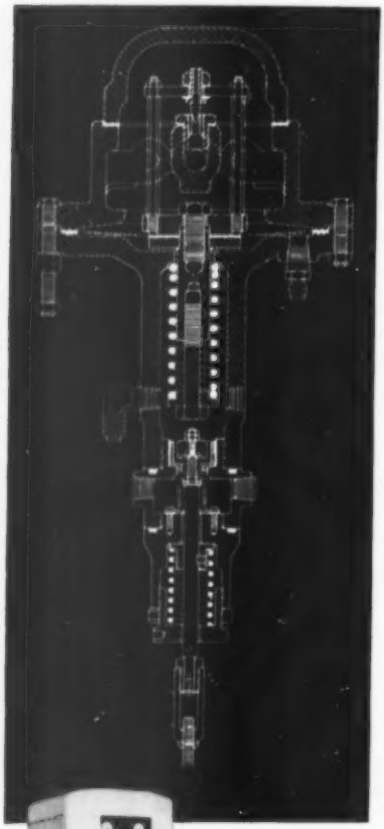
from the University of Wisconsin, and has held various sales posts with the Company, including that of Sales Manager for the pig iron and coke plant which Koppers formerly owned at Granite City, Ill.

Continental Steel Promotes Two

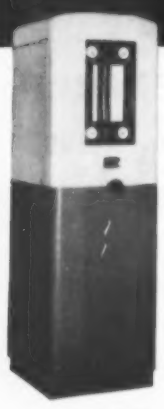
Continental Steel Corporation, Kokomo, Indiana, has announced two new appointments in the Sales Department. Howard C. Williams, Sales Manager of the Sheet Division, is elevated to General Sales Manager. F. A. Lewis, Sales Manager of Chain Link and Ornamental Fence Division, is advanced to Sales Manager of the Merchant Trade Division.

Mr. Williams, upon his graduation from Indiana University in 1934, started with Continental Steel Corporation in the advertising department. Through the years 1937-38-39, Mr. Williams worked in a territory as a sales representative. Returning to the main office in Kokomo, in 1939, he held various positions on his way up through the Sales Department until his appointment as Sales Manager of the Sheet Division in 1946. He has served in this capacity until his present advancement.

F. A. Lewis graduated in 1922 from Case Institute of Technology, Cleveland. Mr. Lewis came with the Continental Steel Corporation in 1930 as District Sales Manager of the Chain Link and Ornamental Fence Division at Toledo, Ohio. In 1934, he was transferred to the main office at Kokomo, and advanced to Sales Manager of this division, a position he has retained until his present promotion.



When users of Builders Chlorinizer tell us (and they often do!) that they never before have worked with such a trouble-free, maintenance-free chlorine gas feeder, we tell them we're pleased — but not surprised — to hear this. You see, there *is* a difference in chlorine gas feeders and basic design makes that difference. For instance, Builders Chlorinizer employs a tantalum diaphragm valve which controls chlorine gas in the dry, non-corrosive state. This valve — the "heart" of the Chlorinizer — is a basic design feature of the Chlorinizer and one of the important reasons why Chlorinizer gives such safe, dependable, low-maintenance operation.



Basic Design makes the Difference

For full details on Builders Chlorinizer, write for Bulletins 840-F1B, 840-J30, 840-J8.

Builders-Providence, Inc. 350 Harris Ave., Providence 1, Rhode Island

BUILDERS

(DIVISION OF B-I-F INDUSTRIES)

New "Runabout" Ditcher

519

Barber-Greene Co., Aurora, Ill., has announced a new "Runabout" Ditcher, the Model 705-B. The new design adds a complete fluid coupling to the fully field-proven "Hydra-crowd" hydraulic transmission.

A second innovation is the design of a special curved-tooth bucket line which increases digging efficiency and assures more than double the normal digging tooth life.

By use of a fluid coupling, the digging mechanism is protected at all times, by a constant hydraulic cushion that eliminates shocks, surge loads, and permits application of full engine horsepower to the task of digging.

With the fluid coupling, underground obstructions, hidden pipes, boulders, roots etc. pose far less of a problem than with any other type of power train. If the obstruction presents too much resistance to the bucket line, the coupling simply slips and the bucket line stops. There is no possibility of damage to the machine, and no additional overload protection devices are required.

The digging range of the Barber-Greene Model 705-B "Runabout" Ditcher is 5½, 7½ and 10½ inches in width and to a maximum depth of four feet.

Permutit Moves West Coast Sales Office

The Permutit Company, New York, N. Y. has announced the removal of its Los Angeles, Calif. sales

(*Continued on page* 125A)

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WATER & SEWAGE WORKS READER SERVICE

READER SERVICE CARDS HOW TO USE THEM

Please fill out a separate coupon for each item on which you desire information. This will greatly facilitate handling.

Key number is at head of each new product, item of equipment, catalog or bulletin, described in this issue.

Enter key number in box.

Please PRINT your name and title, company or department name, and your address

NOTE—

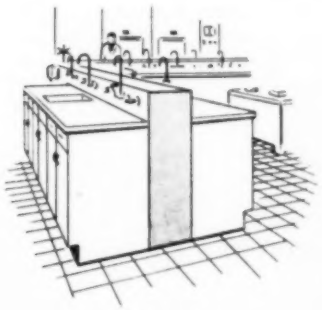
These cards are to be used only for items described in THIS ISSUE

WATER & SEWAGE WORKS

Will see that you receive information desired.

office to a new location at 302-B South Brand Blvd., Glendale 4, Calif.

Mr. George A. Swem will continue in the capacity of Industrial Sales Engineer while Household Sales will continue under the direction of Mr. J. H. Mosher, Pacific Coast Regional Manager.



Filler-Panel for "Island" Laboratory Assemblies

520

Fisher Scientific Co., Pittsburgh, Pa., has developed a one-piece Island Filler-Panel designed to cover the open end of any Unitized "island" or "Peninsula" laboratory assembly.

This island opening, a result of the reagent-shelf extensions, would otherwise reveal the maze of pipes and conduits required to service the modern laboratory bench.

The one-piece Island Filler-Panel is bonderized and finished with three heavy coats of chemically-resistant laboratory-gray paint. Holes of the proper size as well as brackets are provided for easy mounting across the two ends of the adjoining back-to-back units.

V. P. Rumely

L. N. Blugerman

Crane Co. Elects Two Vice Presidents

Crane Co., Chicago, Ill., has announced the election of V. P. Rumely as senior vice president, manufacturing, and L. N. Blugerman as vice president. Mr. Blugerman will have charge of production in the company's plants at Chicago and Chattanooga, Tenn., reporting to Mr. Rumely, who, in addition to supervision of the Chicago Works and Chattanooga Division, will coordinate manufacturing operations in all the plants of the company's subsidiaries.

Mr. Rumely, a Crane director and vice president, joined the company in March 1937, was made Works manager in 1938 and vice president, manufacturing, in 1941.

Mr. Blugerman was made executive assistant of Crane Co. in August, 1952, after 24 years of engineering production and management experience. After graduation from the University of Washington in electrical engineering, he served the United Engineers & Constructors, Inc. for eight years and the Budd Co., Philadelphia, for 16 years. He was general manager of that company's Red Lion plant when he left to join Crane Co.

Howerth Promoted by Gar Wood

Gar Wood Industries, Inc., Wayne, Mich., has announced the appointment of H. J. (Herb) Howerth, Jr., as assistant sales manager of the Wayne division.

Mr. Howerth, who served as chief sales engineer for the Wayne division until his recall to military service two years ago, has just returned from

TANK
with a FUTURE
This tank in some respects looks like hundreds of others, but unlike many, it has a brighter future of longer life and greater service, because it is protected by an Electro Rust-Proofing system.
Efficient control of corrosion on submerged surfaces requires much engineering, some equipment. Careful analysis of your problem . . . design, installation and testing by men who are experienced in their work . . . the "know-how" of an established firm . . . "follow through" of every job—on these and similar engineering details rest effective cathodic protection.
Highly trained, backed by a long list of successful installations and years of experience, our engineer is always ready to help you solve your corrosion problem. For complete information, write today.
ERP-21
ELECTRO RUST-PROOFING CORP. (N. J.)
BELLEVILLE, NEW JERSEY
Over 15 years of cathodic protection engineering, research and development
COMPLETE CATHODIC PROTECTION SERVICE
DESIGN
ENGINEERING
INSTALLATION
MAINTENANCE
EQUIPMENT

a year in Korea where he was a captain with the Army Ordnance Corps. Previously he served as chief of the tank and wheel vehicle branch, procurement division, Ordnance Tank Automotive Center, Detroit. During World War II, Mr. Howerth served with the office of the chief of ordnance procurement in Detroit.

Parsons Co. to Represent A. C. F. in Boston

The American Car and Foundry Company, New York, N.Y., has announced the appointment of W. B. Parsons Company, manufacturers agents, of Boston, Massachusetts, as their representatives in the sale of ACF lubricated plug valves in the Boston area and surrounding territory.

The territory allocated to the Parsons Company will include the state of Massachusetts with the exception of the western county of Berkshire; the states of New Hampshire and Rhode Island and Windham and Tolland counties in Connecticut.

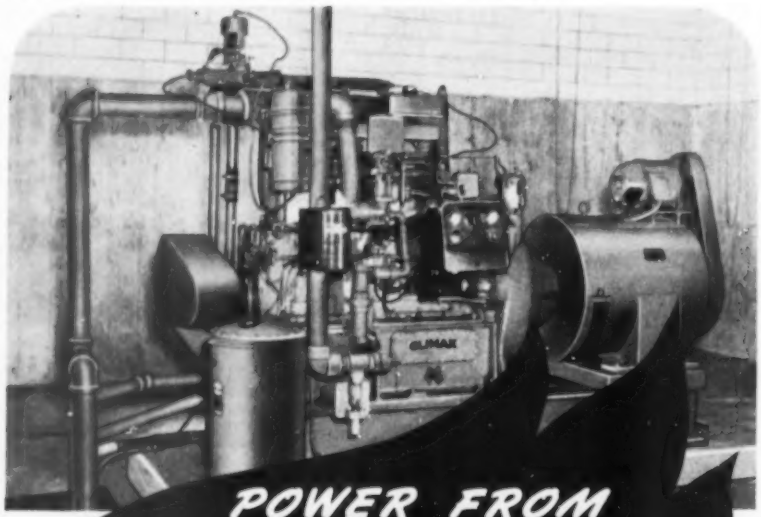
Condensate Return Unit

521

Roy E. Roth Company, Rock Island, Ill., has developed a compact vertical Roth Condensate Return Unit for applications up to 800 sq. ft. EDR at 20 psi. Two sizes cover this range.

The Roth Vertical Condensate Unit handles water to 210°F without vapor lock and the new vertical design is particularly intended for installations where the return piping is close to the floor level. Also, the unit can be installed in a shallow pit, when desired, without risk of flooding the motor which is mounted vertically above the pump and receiver.

The unit is supplied as a complete assembly including pump, choice of cast iron or steel receiver, enclosed float switch, single phase or three-phase motor.



POWER FROM COST-FREE SEWAGE GAS

climax BLUE STREAK ENGINE

OPERATES CONTINUOUSLY ON SEWAGE GAS AT AMES, IOWA

Illustrated is a Climax 50 H.P. sewage gas engine direct connected to a 35 KW generator which operates in parallel with the municipal power service. The amount of power developed varies with the gas supply but the generator produces over 70% of the plant's average power requirements. Jacket water and exhaust heat is utilized in heating the digester.

This plant serves the City of Ames and Iowa State College, a population of 24,000. Its laboratory is used by the college students for research.

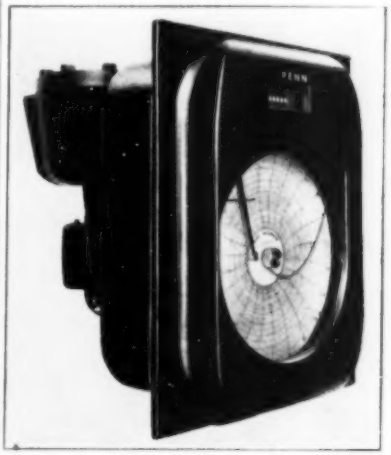
Ames, like many other cities, installed a Climax Engine to do the job because of the minimum operating expense, unmatched dependability, and conservative rating at slow speed.

climax

ENGINE AND PUMP MFG. CO.

Factory and General Office: Clinton, Iowa

Regional Offices: Chicago, Ill., Dallas, Texas



Penn Magna-Clutch

522

Penn Industrial Instrument Corporation, Philadelphia, Pa., has announced an improved mechanical flow and level meter using a magnetic coupling to connect the float in the manometer with the external metering parts. This instrument, known as the PENN Magna-Clutch, has the mercury manometer completely sealed as there are no stuffing boxes or pressure tight bearings. It is particularly desirable for use on toxic, corrosive, or inflammable fluids because no leakage is possible.

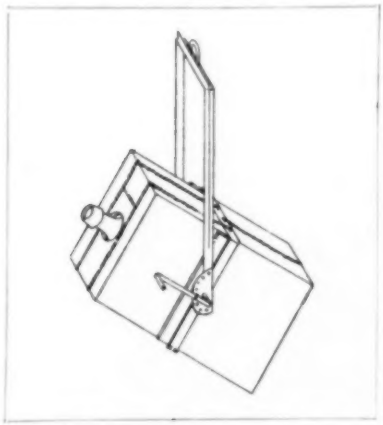
Maintenance is exceptionally low since the principal source of trouble, the pressure bearing, is eliminated. Furthermore, the manometer can be inspected and cleaned and the calibration checked without disconnecting the pressure piping.

The high accuracy obtained through the use of a very large float, long float travel, and friction-less (magnetic) linkage is maintained even at high static pressures with no hystersis.

Great flexibility of differential

range is provided by 7 interchangeable range tubes (20" to 750") and continuous range adjustment down to 50% of maximum for each range. Also manufactured with bell style manometer for low ranges of 4, 6, 8, or 10 inches of water.

Produced in recording, integrating, pneumatic transmitting and controlling styles for static pressures to 2500#.



A Safe, Easy-To-Operate Acid Carboy Dumper

523

General Scientific Equipment Co., Philadelphia, Pa., has available a carboy dumper, for use with hoists or overhead conveyors, that permits quick, safe handling of acids.

The G-S Speedo Safety Carboy Dumper No. 77 can be quickly attached to any over-head hoist for dumping, moving, storing, loading, filling and general handling of acid carboys. An important feature of the dumper is that it permits the carboy to be tilted to any angle and locked in position to asure steady pouring. Chains at the bottom and top of the carboy keep wood from splitting or pulling out during handling. The entire design enables workmen to handle acids safely, economically.

Belco Elects Aldworth Vice President

Belco Industrial Equipment Division, Inc., Paterson, N.J., has announced the election of Edward H. Aldworth as vice president.

Aldworth joined Belco on the first of the year resigning as chief of the Engine and Turbine Division, Water Treatment Equipment Section of the National Production Authority. He served the N.P.A. in that capacity since his appointment and was commended for his contribution to the defense program by former secretary of commerce, Charles Sawyer.

In his new post, he will direct the sale of Belco industrial water treatment equipment in the middlewest with headquarters in Chicago. A recognized authority on water demineralization and purification, Aldworth is a member of both the American Society of Mechanical Engineers and the Institution of Mechanical Engineers of Great Britain.

New Technique for X-Raying Pipes, Valves

524

Sam Tour & Co., New York, N.Y., has announced the technique of "hot radiography" that permits the taking of X-ray photographs of large pipes,

SPRINGLOAD
World's Fastest A-C Pipe Cutter
CUTS CENTURY and TRANSITE PIPE ON THE JOB—NO HAND SAWING

- Cuts Cutting Time 50%
- Cuts Pipe 3" to 24"
- A Portable One-Man Tool
- Cuts Square, True, Smooth
- Requires a Minimum of Maintenance

SPRINGLOAD A-C TENON TOOL
Field Tenons to a Factory Finish

Machines close tolerance, lathe smooth tenon up to 6" length on the job. Eliminates hauling, machine shop costs, adapters. Trues up pipe.
2 Sizes: 4" to 8", 10" to 20".

GRAVITY the GRIP
Lightweight—Portable! Holds any pipe for cutting on the job!
2 Sizes: V-8: 2" to 8"
V-18: 6" to 18"

SALES REPRESENTATIVES:
Write for complete details of the Springload franchise in your territory.

H. D. FOWLER CO., Inc.
P. O. BOX 3084
SEATTLE 14, WASH.

valves, and similar units at temperatures as high as 1200°F.

The process, called the McElroy-McNutt hot radiography process, has been applied with considerable success to the inspection of partially completed welds on hot sections of pipe to check for possible welding defects.

With hot radiography, the usual cooling time is eliminated and makes it practical to interrupt the welding operation to inspect the weld root where most flaws occur. This technique, therefore, saves the many manhours of heating and controlled cooling that were formerly required before the weld could be inspected.

Literature & Catalogs

Wheeler Filter Bottom

525

Builders-Providence, Inc., Providence, R.I., has available **Construction Information on the Wheeler Filter Bottom** (Pre-cast type) for water treatment plants. It explains, with sectional views, the construction of forms, and other field work by the contractor, including placement of the pre-cast blocks, grouting, and general information on costs.

The bulletin illustrates the placing of blocks in a filter box, which should prove useful to those planning a Wheeler Bottom.

Power Distribution Practices

526

General Electric Company, Schenectady, N. Y., has announced a visual program which outlines the latest **Electric Power Distribution Practices** for industrial plants.

The new program presents 12 ideas to help industrial plants maintain power continuity, reduce installation and operating costs, safeguard personnel and equipment, and plan modern, efficient, flexible power systems.

The latest in the G-E More Power to America series of presentations, it consists of a 35-mm sound-color slidefilm, a 28-page power distribution manual, and allied literature with additional product information.

Automatic Engine Stop Valve

527

Golden-Anderson Valve Specialty Co., Pittsburgh, Pa., has available a new 6-page bulletin describing the Golden-Anderson "Cushioned" **Automatic Engine Stop Valve.**

Featured in this bulletin are the application, fabrication, installation and design along with a complete parts list, dimensions for all sizes and complete specifications.

Taping Fundamentals

528

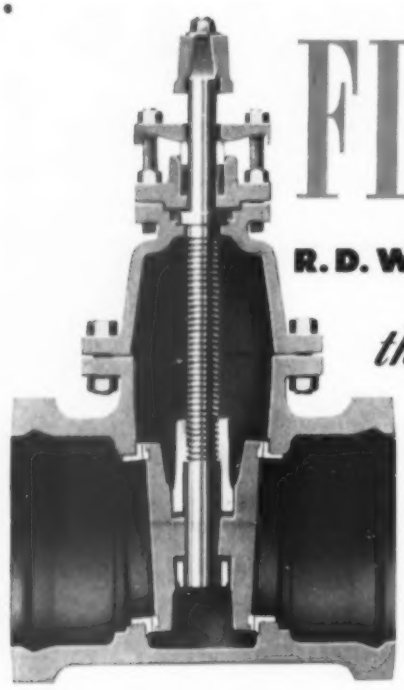
Dresser Manufacturing Div., Bradford, Penna., has just published a bulletin on **Dresser Taping Fundamentals.**

The bulletin gives complete wrapping instructions for wrapping a Cylinder, Pipe Cap or Plug, Bend, Coupling Nut to a Cylinder, Cylinder to Branch, Boltless Coupling, Ells, Tees, and Street Tee, with pressure sensitive Dressertape. These are illustrated with complete step-by-step photographs. The last two pages describe the advantages of using Dressertape.

Motor-Generator Reference Booklet

529

Allis-Chalmers Manufacturing Co., Milwaukee, Wis., has available a **Motor and Generator Reference**



FIRST *choice*

R. D. WOOD GATE VALVES

they LAST

Only three moving parts—the spreader and two discs. In opening, the discs are lifted into the bonnet clear of the seats. In closing, they are wedged into place without distortion. Working pressure up to 175 lb. Tested to 300 lb. Rigidly inspected. Conform to AWWA specifications. Supplied with bell, flanged or mechanical joint pipe connections.

R. D. Wood Gate Valves are first choice with waterworks engineers because they are built to last . . . and last . . . and last. Made from seasoned castings, fully bronze mounted. Their simplicity of design gives generations of trouble-free operation.

150th anniversary

R.D.Wood

COMPANY

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers of Mathews Hydrants and "Sand-Spun" Pipe (centrifugally cast in sand molds)

Booklet to assist in the selection of motive power to handle most industrial applications.

The 50-page pamphlet is reprinted from the 1952 edition of Lincoln's Industrial - Commercial Electrical Reference published by the Electrical Modernization Bureau, Inc. Text and illustrations on integral horsepower motors and generators for the book were furnished by Allis-Chalmers in cooperation with the Electrical Modernization Bureau.

New Synthetic Hard Rubber Pipe and Fittings

530

American Hard Rubber Company, New York, N. Y., has just published a new bulletin describing **TEMPRON,** a new heat and chemical resistant synthetic hard rubber compound. According to the bulletin, Tempron is ideal for pipe and fittings, has greater rigidity, heat resistance and chemical resistance than other soft or hard nitrile-base compounds hitherto available. In chemical resistance at elevated temperatures it excels other rubber and plastic materials. At room temperature it resists many organic chemicals which attack natural rubber, soft rubber and plastics. TEMPRON is also available as sheet, rod and tubing and molded parts.

This bulletin gives complete information on pipe and fitting sizes as well as data covering the physical and electrical properties of TEMPRON.

Corrosion Prevention of Tanks by Metallizing

531

Metal-Cladding, Inc., Buffalo, New York, has published a bulletin on **Corrision Prevention with Metallized Zinc or Aluminum.**

The bulletin shows by means of actual installation photographs and descriptive text the operation of metallizing and how water tanks and riser pipes after being metallized show no signs of corrosion after 15 to 20 years.

A description of the various metallizing systems and recommended metals to combat specific corrosion problems completes the bulletin.

ElectroniK Controller

532

Minneapolis-Honeywell Regulator Company, Brown Instruments Division, Philadelphia, Pa., has just published a boklet on **ElectroniK Controllers.**

The booklet is comprised of 56 fact-filled pages describing all types of ElectroniK control instruments which are used to measure and control a multiplicity of process variables. Included are detailed specification and control action descriptions and ratings for both electric and pneumatic type controllers.

The literature also presents engineering data on the Electr-O-Line and Electr-O-Pulse electric control relays.

The Story of Diatomite

533

Johns-Manville, New York, N. Y., has just published a new 28-page brochure, **Celite—The Story of Diatomite."** Designed for both laymen and technical men, it uses photographs and drawings as well as text to trace the development of diatomite.

The story begins with the arrival of the diatom during the Miocene Era. This first section tells what a diatom is and explains how these marine organisms emerged as the

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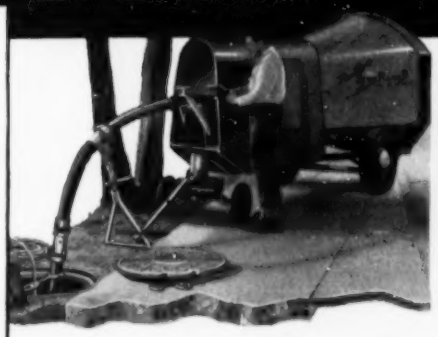

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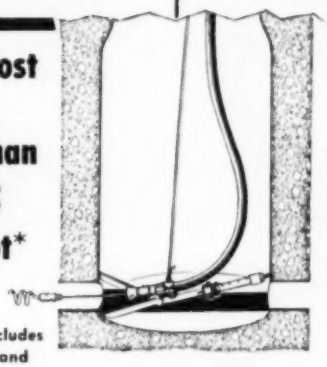

*This figure includes maintenance and parts replacement.

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—Is a mechanical marvel that does all rodding with two men — eliminating 9/10ths of the usual hard labor in a day's work. It's increased, low cost capacity permits "preventative maintenance" to be carried on inexpensively —and eliminates costly emergency work. Rod reel contains 900 feet of rods for instant use. Imparts a rotating action to rods and tools. Truck mount models also available.

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AMERICA'S LARGEST MANUFACTURER
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unique deposit in California known as the White Hills of Lompoc. The next section deals with discovery of this deposit and the experiments which have led to the still-multiplying uses of diatomite today.

The succeeding sections of the brochure describe the current benefits of diatomite—as filter powder for water purification, dry cleaning and the production of foods and beverages; as a mineral filler in the manufacture of paint, plastics, paper, fertilizers and insecticides; as a high temperature insulation; and, as a catalyst carrier wherever silica is indicated.

The story concludes with a brief predication of new things that may be expected.

Telemetering Booklet

534

Bristol Company, Waterbury, Conn., has just published a new booklet on **Telemetering.**

The booklet, Bulletin M1710, contains information on the use of the company's Metameter telemetering instruments for remote recording, indicating and control of variables over distances ranging from a few feet to many miles. A great deal of timely information and engineering data are given on the subject of modern methods of telemetering.

A number of typical installations of Metameter telemeters and remote pump controls in use on water distribution systems throughout the country are illustrated and described. Among the applications given are remote readings of water level in reservoirs, lakes, rivers, and storage tanks; flow through flumes and weirs, pressure in high pressure and distribution mains; and remote automatic pump control.

USE UNTRAINED LABOR

McWANE-PACIFIC *Boltite* PIPE

One man can assemble and make up Boltite mechanical joints. He needs no special skill or training. He needs only one tool—a ratchet wrench. All he does is socket the spigot in the bell, slip the gasket into the stuffing box thus formed, then tighten the bolts of the follower-ring or gland. This simple procedure in joint making saves time, saves labor, saves money.

Boltite is an ideal mechanical joint for water or gas, steam, oil, chemicals or other liquids. Gaskets are furnished of materials to suit the service required. Boltite joint parts are interchangeable with any make of Standardized Mechanical Joint for Cast Iron Pipe. For further details, write

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Portland 4, Oreg.	501 Portland Trust Bldg.
Salt Lake City	Waterworks Equip't Co.
Seattle, Wash.	Smith Tower Bldg.

Screw Conveyor Book

535

Link-Belt Company, Chicago, Ill., has just released a comprehensive 92-page book on **Screw Conveyors and Screw Feeders.**

The book gives detailed engineering information, with selection tables and horsepower formulas, layouts and arrangements, dimensional data and part numbers, to permit selection of screw conveyors and screw feeders for many types of applications. Installation photographs show screw conveyors used for conveying, elevating, heating, cooling and mixing.

Engineering data and component specifications comprise 54 pages of the book. Many practical suggestions for correct selection and arrangement of components are included.

Milivoltmeter Type Instruments

536

Minneapolis-Honeywell Regulator Company, Brown Instruments Division, Philadelphia, Pa., has just published a catalog that describes **Brown Millivoltmeter Type Instruments:** Indicators, Indicating Electronic Controllers and Excess Temperature Safety Cut-Off Controllers.

Information on operation and applications of on-off, two-position, three-position and "pulse type" time-proportioning controllers is included as well as data on primary measuring elements, dimensions, ordering information and scale selection tables.

The Story of Alum

537

American Cyanamid Company's Industrial Chemicals Division, New York, N.Y., has just published a booklet describing **Alum, Commercial Aluminum Sulfate.** Illustrated

with charts and graphs, the booklet explains what aluminum sulfate (alum) is, and outlines its numerous industrial applications.

Sections of the booklet include: What is Alum; History of Alum; Manufacture of Alum; Properties of Alum; Alum in the Treatment of Municipal and Industrial Water Supplies; Alum in the Treatment of Sewage and Industrial Wastes; Alum in the Paper and other Industries; Alum Handling Systems, and Cyanamid Alum.

TS Diesel Bulletin

538

Ingersoll-Rand, New York, N.Y., has just published a new bulletin on the **TS Diesel Engine.** This 12-page, 3-color catalog incorporates sectional wash drawings, installation views, and diagrams to show why the TS Diesel is called a smaller, lighter, but fully heavy-duty engine. It is a 7" x 8½", 900 to 1000 rpm Diesel in the 200 to 400 hp. class.

Specifications, weights, performance curves, and dimension tables are also included in this bulletin.

Heavy Duty Rotary Pumps

539

Worthington Corporation, Harrison, N.J., offers a new bulletin on **Heavy Duty Rotary Pumps.**

Covering both the Herringbone Gear Type, with capacities to 5,000 gallons-per-minute, pressures to 100 pounds per square inch; and the Sliding-Vane Type, with capacities to 1,000 gallons per minute, pressures to 200 pounds per square inch, the new bulletin is complete with fields of application, coverage charts, mountings and dimensions.

Engineering Data in the new bulletin includes a viscosity conversion table, Relation of A.P.I. Hydrometer Scale to Specific Gravity, and a Viscosity-Temperature Chart for Fuel Oils.

Practical Applications of Metallizing

540

Metallizing Engineering Co., Inc., Long Island City, N.Y., has published a new general bulletin that covers a wide range of **Practical Applications of Metallizing** in machine maintenance and repair, production, production salvage and corrosion prevention. The 8-page, illustrated bulletin discusses the characteristics of sprayed metal, describes in general where metallizing is used, its general advantages and limitations. Some of the jobs illustrated include the repair of worn crank shafts, pump packing sleeves, press rams, turbine rotors and stators, rolls, motor shafts, pistons, cylinders, etc.

This bulletin, also includes a number of case histories which describe in detail the savings in time and money effected on various typical metallizing jobs.

Rubber Lined Sand Pumps

541

Denver Equipment Company, Denver, Colo., has published a bulletin describing and illustrating the reasons why pressure molded rubber parts in the Company's SRL **Rubber Lined Sand Pumps** maintain high efficiency for prolonged periods.

Case histories are given that show rubber parts last from six to fifty times longer than the best hard iron or steel parts. According to the bulletin the simplicity of construction of the pumps means that they are easier to operate and maintain.

This 20-page bulletin lists all parts and shows them by sectional views, lists clearance and foundation dimensions, specific gravity of pulps, friction of water in pipes, SRL pump capacities, a motor selection table, installation and maintenance instructions.

To the four corners of the earth PEKRUL GATES are performing efficiently and dependably. PEKRUL Water Control Equipment is designed and developed to meet the most rigid requirements anywhere in the world.

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Write for Catalog 49

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DAM REBUILT WITH "GUNITE"

This is Lower Doughty Pond Dam belonging to the Atlantic City, New Jersey, Water Department, a poured concrete structure with fresh water upstream and tide water at the downstream toe. This structure became seriously disintegrated and eroded as shown in the upper photo, and was completely restored with "GUNITE" a minimum of six inches in thickness with double mesh reinforcement.

The lower view shows the finished job completed by us in 1941. Both the upstream and downstream faces were restored with "GUNITE", as well as the wing walls.

Our 72-page general bulletin C2400 describes this and scores of other uses of "GUNITE". We shall be glad to send it to you upon request.

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GENERAL OFFICES—ALLENTOWN, PENNA. U.S.A.
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OVER 50 YEARS EXPERIENCE
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Duplex Sewage Ejector, showing inlet piping.

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TO LIFT SEWAGE AND SLUDGE AT TREATMENT PLANTS

30 to 500 GPM in both single and twin units against high discharge heads.

Over 50 years service has proved the rugged worth of Blackburn-Smith Ejectors. Yet our today's product is full of exclusive modern features such as:

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Any one of the above, with or without Air Receivers.

Preferred by most prominent consulting engineers as less messy, more sanitary than centrifugal submerged type sewage ejectors or pumps. Ends screen and pump cleaning. Sewage can be lifted straight up—150 feet—any capacity—once a minute, without fail. Catalog S 50

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Controlled Volume Pumps

542

Milton Roy Company, Philadelphia, Pa., has just published a bulletin describing a recent addition to the Milton Roy family of **Controlled Volume Pumps.** According to the bulletin the H-20 positive displacement pump is designed for those water treating and other industrial applications which do not require the extreme accuracy offered by the Milton Roy Stepvalve construction.

This four page bulletin contains valuable information covering applications, capacities, materials of construction, motor-drivers and prices.

Roller Chains and Sprockets

543

Baldwin-Duckworth, division of Chain Belt Company, Milwaukee, Wis., has just published a new bulletin on Baldwin-Rex Roller Chains and Sprockets.

The 54 page book describes the inherent advantages of roller chain, and illustrates all the popular sizes of Baldwin-Rex Roller Chains. A section of the bulletin is a treatise on "how to select standard roller Chain drives" . . . with formulas, tables and examples illustrating this procedure. Roller Chain dimensions, strengths, weights, and prices are included.

An important section of the bulletin deals with stock sprockets . . . their characteristics and prices. Bore, keyway and setscrew information is presented. Proper maintenance of chain drives is reviewed, and important information on chain vises, flexible couplings and coupling covers is provided.

Corrosion-Resisting Technical Coatings

544

The Earl Paint Corporation, Utica, N.Y., has just published a new 24 page catalog listing a complete line of coatings for industrial mainte-

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Graduate Sanitary Engineers for starting operation of sewage treatment plants for equipment manufacturer. Opportunity for advancement in Engineering or Sales Engineering. Excellent opportunity for learning sewage treatment thru operation. Operation job requires extensive traveling from Chicago. Initial training period provided.

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nance, including corrosion-resisting, insulating, waterproofing and restoration materials. This catalog gives detailed descriptions of **Erkote products**—their composition, qualities, uses, test to which they have been subjected and results thereof. Of particular interest is a section containing technical data and tables showing the outstanding chemical, corrosion and fire resistance, as well as insulation qualities of the various Erkote Mastics. The Catalog contains many photographs illustrating typical applications and recommendations for coating various items of equipment. Also included is a description of Earl Paint Corporation's "One Responsibility" contract service offered through a wholly-owned subsidiary, a unique industrial service feature.

Shovels and Truck Cranes

545

Gar Wood Industries, Inc., Wayne, Michigan, has announced a new four color catalog describing the **Model 75A and 75B Shovels** and the 75BT truck crane.

This new catalog describes in detail the many construction and operational features such as the fluid coupling which absorbs and cushions shocks, thereby prolonging the life of the unit. Other features described are the exclusive right angle gear drive which eliminates adjustments, is completely sealed in oil; power actuated hoist clutches permit ease of operation and greater output; heavy duty conical rollers eliminate pin strain and carry the tipping loads; power steering means easier turns even on rough ground.

The new catalog also points out the ability of the 75's to hoist, swing and travel simultaneously. Independent chain crowd is mentioned as one of the features which reduces conversion time.

Safety Tread Information In Handy File Form

546

Wooster Products, Inc., Wooster, Ohio, has just printed a new file size folder on **Safety Treads.** It provides detailed information on practically every type of safety tread application.

The folder contains 28 plates of details on abrasive cast and safe grove treads as well as expansion plates, platforms, curb bars and floor grids. The various tread surfaces of Ferrogrit, Alumogrit, Bronzogrit and Nicklogrit are also described. Full size cross-sections of the various types are shown in addition to dimension drawings, typical installation and mechanical specifications.

Diesel Engine "Primer"

547

P&H Diesel Division, Harnischfeger Corporation, Crystal Lake, Ill., has just published a unique and informative new booklet on diesels, written in simple, non-technical language.

Entitled, **"What You Should Know About Diesel Engines,"** it effectively calls upon the grade school "primer" technique for both telling and illustrating the diesel story. Its main objective is to show just how simple the modern diesel engine is and how easy it is to understand its operation. The booklet records the diesel engine's invention and early development; compares it with the gasoline engine; tells about the 2-cycle and 4-cycle types of diesels; explains its operation in simple pictures and words; and reports latest advancements in modern diesel engine design.

The new 2-color booklet is in handy pocket size and has dozens of illustrations in its 28 pages.

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Widths
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★ For PERMANENTLY repairing broken or cracked pipe

By utilizing the flexibility, durability and strength of copper or stainless steel, the Smith-Blair Full Circle Clamp Coupling has proved itself to be a revolutionary repair unit. It is fast becoming the standard method of repair for the water works throughout the United States and Canada. It is a permanent repair unit for any type of pipe.

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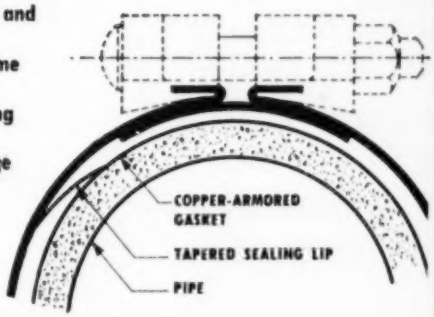

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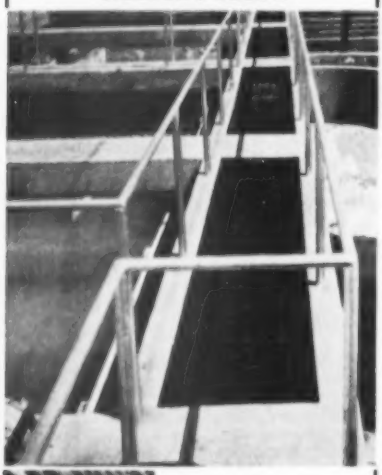

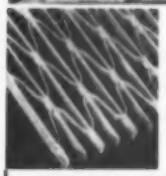

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Water in Air-Conditioning Systems

548

Water Service Laboratories Inc., New York, N.Y., has just published a bulletin entitled **"Use of Water in Air-Conditioning Systems."**

This bulletin discusses the use of recirculated water in the component parts of air-conditioning systems, such as cooling towers and evaporative condensers. It describes the operating troubles directly arising from the impurities that are present in all natural waters, and it gives recommendations for overcoming these troubles.

Helical Gear Drives

549

Link-Belt Company, Chicago, Ill., has just published a new, illustrated 16-page booklet on **Helical Gear Drives** and discusses their advantages, fields of application and correct selection.

Full-page cross-sectional views show in detail the design and construction features of both the double and triple reduction types. Installation photographs picture typical installations.

All factors governing correct selection are described in detail. The right drive for any application can be chosen readily, because horsepower ratings for all drives, in all ratios, for various input speeds, are shown in tabular form.

Load classes for 170 types of machines, arranged alphabetically from agitators to windlasses, are tabulated. Other tables give the maximum overhung loads for drives of various sizes. Principal dimensions of the various drives are shown.

Liquid Level Gages

550

Jerguson Gage & Valve Company, Somerville, Mass., has released a set of **New Data Units on Liquid Level Gages.**

Nine sheets covering the complete line of Liquid Level Gage Valves for both Tubular and Flat Gages, regular, offset and with union connections to gage. Complete specifications with illustrations showing cross sections, roughing dimensions, standard and optional connections available are also given.

Rotary Gravity Filter

551

Minneapolis-Honeywell Regulator Company, Brown Instruments Divi-

TRANSITE FILTER BOTTOMS
CUT YOUR FILTRATION COSTS

Check
THESE FEATURES:
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✓ long-lasting materials
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• Made so gravel cannot clog or obstruct ports, these strong, durable transite filter bottoms are stable under all conditions. Easily assembled with only a screwdriver in 5 minutes.

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Mechanical joints provide "bottle-tight" connections and high speed, economical installations.

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Precision engineering is combined with rugged construction for smooth operation, easy maintenance and pleasing appearance.

Built to conform to latest A.W.W.A. specifications in every respect.

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IOWA
VALVE COMPANY
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A subsidiary of James B. Clow & Sons

sion, Philadelphia, Pa., has published a new data sheet that describes instrumentation and uses of the **Waco Rotary Gravity Filter.**

The information in this sheet is of particular interest to those industries, such as the pulp and paper industry, where large sewer effluents require an effective means of reducing stream pollution and recovering valuable products.

How to Reduce Refuse Collection Costs

552

Gar Wood Industries, Inc., Wayne, Michigan, has issued a colorful new 12-page catalogue titled **"How to Reduce Refuse Collection Costs."**

The catalogue illustrates and describes the new Gar Wood Load-Packer, presenting statistics and examples of how every sized community can reduce refuse collection cost and offer better service to its citizens.

Cut-away drawings explain the new Load-Packer automatic compacting cycle which eliminates lost time during loading and enables Load-Packers to attain up to 200% bigger loads. Also illustrated are the advantages of the low, wide hopper, large side doors and the elimination of selected loading. Other features described are the tapered body, smooth interior and high dumping angle for fast complete dumping; the improved hydraulic system; shorter wheel base for narrow alley operation; and the leak and odor factors which insure more sanitary collection.

V-Belt Catalog

553

Raybestos-Manhattan, Inc., Manhattan Rubber Division, Passaic, New Jersey has published a new fractional horsepower **V-Belt Catalog** for use in servicing light duty applications.

In this catalog belts are listed according to the new industry-standard numbering system. Various type machines are listed together alphabetically by company or trade names for convenience in determining the proper belt.

FOR SALE
Terry Steam Turbine Centrifugal Pump 4 Stage, Capacity 28 M. G. 500 Foot Head, Special Piping Condenser.
J. W. MAGLAUGHLIN, JR.
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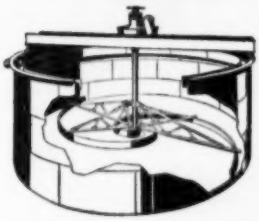
THICKENERS

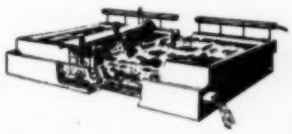


For removal or reclaiming of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Bulletin 31-D-15.

CIRCULAR CLARIFIERS

Light and heavy-duty clarifiers for water or sewage, either beam or center-column type, central sludge discharge. Bulletin 35-C-15.

AUTOMATIC BACKWASH SAND FILTERS



For high removal of non-settling or slow-settling suspended matter. Self-cleaning sand bed. No shut-down necessary for back-washing. Traveling backwash carriage. Bulletin 46-A-15.

RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. Particularly suited to sewage treatment, industrial wastes, and oil-water separation in refinery waste water treating. Bulletin 31-D-15.

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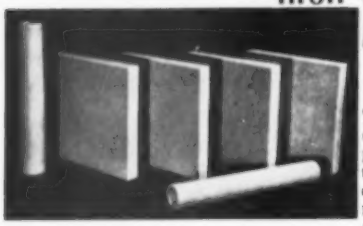

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554

Southern Pipe & Casing Co., Azusa, Calif., has just published a catalog on **Automatic Electric Fusion Welded Steel Pipe.**

This new, 42-page catalog contains a wealth of information on the many interesting steps in pipe making, as well as the latest procedures in the applications of various protective coatings.

Occasion for the issuance of the new catalog is the Company's celebration of its 20th anniversary in the welded steel pipe manufacturing business.

The Catalog provides engineers and estimators with a great amount of up-to-date information on specifications, prices and weights. This data, together with the many pictorial descriptions of fittings, field joints, protective coatings and types of pipe, from 4" to 36" in diameter, make the "Southern" Catalog a handy reference manual for every pipe user.

New Condensed Catalog Covers McDonnell Products

555

McDonnell & Miller, Inc., Chicago, Ill., has published a **Condensed Catalog & Price List.**

The catalog covers McDonnell boiler water feeders, low water fuel cut-offs, pump controls and relief valves —including the recently announced McDonnell temperature relief valves and combination T & P relief valves, in both regular and dip tube models.

This 8-page catalog has the information so arranged as to simplify selection of proper equipment, and is complete with prices.

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Herringbone Gear Drives

556

Link-Belt Co., Chicago, Ill., has just published a new 36-page book on **Herringbone Gear Drives.** It offers detailed information about Link-Belt single, double and triple reduction enclosed herringbone gear drives. The book shows how herringbone gear drives are widely used to transmit power at required speeds to conveyors, line shafts, blowers, pumps, agitators, hoists, machine tools, processing machines and other industrial equipment.

The horsepower rating tables in the book contain many new ratios. Ratings for input speeds of 720 to 1750 r.p.m. are given for all drive sizes. Complete instructions for correct selection are provided, including new overhung load tables and a table listing load classes for 170 types of machines.

Also listed are 39 sizes of drives in 534 standard ratios, from 2.84:1 to 326:1. Capacities range from 0.4 to 2480 horsepower, and output shaft speeds range from 2.2 to 623 r.p.m.

Clorpactin XCW

557

Guardian Chemical Corporation, New York, has published a technical bulletin describing an unusual new material known by the trade mark name of **Clorpactin XCW.**

The bulletin recommends Clorpactin XCW for treatment of sewage, water pollution and industrial wastes, and points out that unlike other chlorine sanitizers, Clorpactin XCW is not readily inactiviated by the presence of organic matter.

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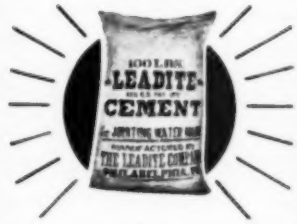

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- Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

AMMONIATORS
- Amer. Water Softener Co., Philadelphia 33, Pa.
- Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
- Wallace & Tierman, Newark 1, New Jersey

ANTHRAFILT
- Amer. Water Softener Co., Philadelphia 33, Pa.
- Anthracite Equip. Co., Anthracite Institute Bldg., Wilkes-Barre, Pa.
- Permutit Co., 330 W. 42nd St., New York 36, N. Y.
- Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
- Walker Process Equip., Inc., Aurora, Ill.

AQUAPHONES
- Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
- Northrup & Co., Inc., Spring Valley, N. Y.

ARRESTERS, FLAME
- H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
- Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

ASBESTOS-CEMENT PIPE
(See Pipe-Asbestos Cement)

ASH AND COAL HANDLING MACHINERY
- Bucyrus-Erie Co., South Milwaukee, Wis.
- Chain Belt Co., Milwaukee 1, Wis.
- The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
- Link-Belt Co., Colmar, Pa.
- Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

BAR SCREENS
(See Screens, Sewage)

BINS, Storage
- R. D. Cole Mfg. Co., Newnan, Ga.
- Hammond Iron Works, Warren, Pa.
- The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
- Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

BITUMINOUS COATINGS AND LININGS
- Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
- Atlas Mineral Prod. Co., Mertztown, Pa.
- Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
- Centriline Corp., 140 Cedar St., New York 6, N. Y.
- Electro-Chemical Engr. & Mfg. Co. Broad & Grant Sts., Emmaus, Pa.
- Johns-Manville Corp., 22 East 40th Street, New York 16, New York
- Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
- Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
- Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
- U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio

BLACK ALUM
(See Activated Alum)

BLEACHING POWDER
(See Calcium Hypochlorite)

BLOWERS AIR, GAS (Centrifugal and Rotary)
- Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
- De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
- General Electric Co., Schenectady, N. Y.
- Homelite Corp., Port Chester, N. Y.
- Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
- Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
- Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
- U. S. Hoffman Mach., Corp., 111 Fourth Ave., New York 3, N. Y.
- Worthington Corp., Harrison, N. J.

BOILER BREECHINGS
(See Breechings, Steel)

BOILER FEEDWATER TREATMENT AND EQUIPMENT
- Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
- Chain Belt Co., Milwaukee 1, Wis.
- Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
- The Dorr Co., Barry Place, Stamford, Conn.
- Hardinge Co., Inc., 240 Arch St., York, Pa.
- Hays Corp., East 8th St., Michigan City 31, Ind.
- Hellige, Inc., 37-18 Northern Blvd., Long Island City 1, N. Y.
- Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
- Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
- Permutit Co., 330 W. 42nd St., New York 36, N. Y.
- Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
- Proportioneers, Inc., 345 Harris Ave., Providence, R. I.
- Roberts Filter Mfg. Co., Darby, Penn.
- Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
- Worthington Corp., Harrison, N. J.

BOILERS, GAS
- American Radiator & Standard Sanitary Corp., P. O. Box 1226, Pittsburgh 30, Pa.
- R. D. Cole Mfg. Co., Newnan, Ga.

BOOKS, TECHNICAL
- McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y.
- The MacMillan Co., 60 Fifth Ave., New York 11, New York.
- Phipps & Bird, Sixth & Bird St., Richmond, Va.
- John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER
(See Valve Boxes; Meter Boxes)

BRASS GOODS
(See also Pipe, Brass)
- American Brass Co., 414 Meadow St., Waterbury 20, Conn.
- Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
- H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash
- A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
- Mueller Co., 215 W. Cerro Gordo St., Decatur 70, Ill.
- Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
- A. P. Smith Mfg. Co., E. Orange, N. J.
- Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

BREECHING, STEEL
- Bethlehem Steel Co., Bethlehem, Pa.
- Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago.
- R. D. Cole Mfg. Co., Newnan, Ga.
- Hammond Iron Works, Warren, Pa.
- Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BRONZES (Special Alloy)
- American Brass Co., 414 Meadow St., Waterbury 20, Conn.

BUFFER SOLUTIONS & TABLETS
- Beckman Instruments, Inc., South Pasadena 1, Calif.
- Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
- Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
- W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
- Wilkens-Anderson Co., 4525 W. Division St., Chicago 57, Ill.

BUCKET ELEVATORS
(See Conveyors and Conveying Equip.)

BUTTERFLY VALVES
(See Valves, Butterfly)

CABLE
- Bethlehem Steel Co., Bethlehem, Pa.
- General Electric Corp., 1 River Road, Schenectady, N. Y.
- Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

CALCIUM HYPOCHLORITE
- John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
- Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Md.
- Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
- Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

CARBON-ACTIVATED
(See Activated Carbon)

CARBONATORS (Recarbonation)
- American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Walker Process Equipment Inc., P. O. Box 266, Aurora, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.

Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
Bethlehem Steel Co., Bethlehem, Pa.
Cast Iron Pipe Research Assoc., 122 So. Michigan Ave., Chicago.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
The Filer & Stowell Co., 147 E. Becher St., Milwaukee 7, Wis.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hardinge Mfg. Co., 240 Arch St., York, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5.

CAST IRON PIPE

(See Pipe)

CATCH BASIN CLEANERS

Rootes Motors, Inc., 27-11 Bridge Plaza, Rd., Long Island City 1, N.Y.

CATHODIC PROTECTIVE SYSTEMS

Chicago Bridge & Iron Co., 332 South Michigan Ave., Chicago.
Dow Chemical Co., Midland, Mich.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Electro Rust-Proofing Corp. (N. J.), Belleville 9, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.

CAULKING MACHINES & TOOLS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

CEMENT ASBESTOS PIPE

H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Johns-Manville, 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.

CEMENT GUN

Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.

CEMENT LINED PIPE

(See Pipe, Cement Lined)

CEMENT LINING OF PIPE

Centriline Corp., 140 Cedar St., New York 6, N. Y.
Pipe Linings, Inc., 4675 Firestone Blvd., South Gate, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CEMENTS, ACID PROOF & ALKALI PROOF

Atlas Mineral Prod. Co., Mertztown, Pa.
Electro Chemical Engr. & Mfg. Co., Broad and Grant Sts., Emmaus, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.

CEMENTS, REFRACTORY

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Phipps & Bird, Sixth & Byrd St., Richmond, Va.

CEMENTS, SEWER PIPE

Atlas Mineral Prod. Co., Mertztown, Pa.
Electro Chemical Engr. & Mfg. Co., 758A Broad St., Emmaus, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.

CEMENTS, WATER MAINS

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.

CHAINS (Elevating, Conveying and Power Transmission)

Chain Belt Co., Milwaukee 1, Wis.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Link-Belt Co., Colmar, Pa.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.

CHEMICAL CONTROL EQUIP.

(See Laboratory Apparatus and Reagents)

CHEMICAL, CONVEYING EQUIPMENT

Chain Belt Co., Milwaukee 1, Wis.
Hardinge Co., Inc., 240 Arch St., York, Pa.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Link-Belt Co., Colmar, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wallace & Tiernan, Box 178, Newark 1, N. J.

CHEMICAL FEEDING AND PROPORTIONING EQUIPMENT (Dry and Solution—Also see Chlorinators)

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 850 Harris Ave., Providence, R. I.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
F. B. Leopold, 2413 W. Carson St., Pittsburgh 4, Pa.
Manzel, Inc., 244 Babcock St., Buffalo, N.Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Omega Machine Co., 345 Harris Avenue, Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Terminal Annex, Los Angeles, Calif.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.
Syntron Co., 650 Lexington, Homer City, Pa.
Wallace and Tiernan, Box 178, Newark 1, N. J.

CHLORINATORS

(See also Hypochlorinators)

Amer. Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Builders - Providence, Inc., 850 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Box 178, Newark 1, New Jersey.

CHLORINATORS (Cleaning Solutions)

Lake Products Co., Inc., 1254 Grover Rd., St. Louis 23, Mo.

CHLORINE CONTROL EQUIPMENT

(See Residual Chlorine Control)

CHLORINE DIOXIDE

(See Sodium Chlorite)

CHLORINE, LIQUID

Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Solvay Process Div., Allied Chemical & Dye Corp., 61 Broadway, New York 6, N. Y.

CLAMPS AND SLEEVES, PIPE

Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT

Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
H. Y. Carson Co., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

CLAMPS, PIPE REPAIR

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Joseph G. Pollard Co., New Hyde Park, N. Y.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

CLARIFIERS, SEWAGE AND WATER

American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Cochrane Corp., 17th St. and Allegheny Ave., Philadelphia, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

CLAY PIPE

(See Vitrified Clay Pipe and Products)

CLEANERS, CATCH BASIN

(See Catch Basin Cleaners)

CLEANING SOLUTIONS, CHLORINATORS

(See Chlorinators, Cleaning Solutions)

CLEANING WATER MAINS

Ace Pipe Cleaning Contractors, Inc., 3513 East 13th St., Kansas City 1, Mo.
Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York City.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

COAGULATING AIDS

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

COAL AND ASH HANDLING MACHINERY

(See Ash and Coal Handling Machinery)

COATINGS, ACID AND ALKALI-PROOF

Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Electro-chemical Engr. & Mfg. Co., Broad and Grant Sts., Emmaus, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Johns-Manville Corp., 22 East 40th St., New York 16.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio

COATINGS AND LININGS

(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corporation, Etc.)

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Ford Meter Box Co., Wabash, Ind.

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

COLLECTORS (Sludge)
(See Sludge Collectors)

COLORIMETERS
(See Photoelectric Colorimeters)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.

COMMINUTING DEVICES
(See Grinders also)
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Infilco, Inc., Tucson, Ariz.
Process Engineers Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Worthington Corp., Harrison, N. J.

COMPARATORS, COLOR
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace and Tiernan, Box 175, Newark 1, N. J.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 57, Ill.

COMPOUNDS, JOINT
(See Jointing Compounds and Materials)

COMPRESSORS, AIR
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind
U. S. Hoffman Mach. Corp., 111 4th Ave., New York 3, N. Y.
Worthington Corp., Harrison N. J.

CONCRETE BREAKERS
Homelite Corp., Port Chester, N. Y.
Syntron Co., 650 Lexington, Homer City, Pa.
Worthington Corp., Harrison, N. J.

CONCRETE HARDENER
Diamond Alkali Co., Pittsburgh.
Dow Chemical Co., Midland, Mich.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Solvay Process Div., Allied Chemical & Dye Corp., 61 Broadway, New York, N. Y.

CONCRETE JOINT WATER SEALS
Water Seals, Inc., 9 S. Clinton St., Chicago 6, Ill.

CONCRETE MIXER
Chain Belt Co., Milwaukee 1, Wis.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, Ohio
Worthington Corp., Harrison N. J.

CONCRETE PIPE
(Water and Sewage)
American Concrete Pressure Pipe Assn., 228 N. LaSalle St., Chicago 1, Ill.
Lock-Joint Pipe Co., P.O. Box 269, East Orange, N. J.
Price Bros. Co., P. O. Box 825, Dayton 1, Ohio

CONDENSERS (Steam)
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
R. D. Cole Mfg. Co., Newnan, Ga.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

CONTRACTORS (Water and Sewage Works)
Cement Gun Co., P.O. Box 424, Allentown, Pa.
Hammond Iron Works, Warren, Pa.
Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tennessee.
Municipal Service Co., 210 W. 10th St., Kansas City, Mo.
Ranney Method Water Supplies, Inc., P. O. Box 277, Columbus 9, Ohio
Roberts Filter Mfg. Co., Darby, Pa.
Welsbach Corp., Cons. Div., 1500 Walnut St., Philadelphia 2, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Pike Hoffman Control Co., 272 E. 5th St., St. Paul, Minn.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Charles F. Warrick Co., 1964 W. Eleven Mile Road, Berkley, Mich.

CONVEYORS AND CONVEYING EQUIPMENT
American Well Works, 100 N. Broadway, Aurora, Ill.
Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Chain Belt Co., Milwaukee 1, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Syntron Co., 650 Lexington, Homer City, Pa.
Walker Process Equip. Inc., P. O. Box 266, Aurora, Ill.

COPPER SULFATE
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Tennessee Corp., 617-29 Grant Bldg., Atlanta 1, Ga.

COPPER TUBING AND RED BRASS PIPE
The American Brass Co., 414 Meadow St., Waterbury 20, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

CORPORATION & CURB COCKS
(See Cocks-Corporation, Curb and Meter)

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh 22, Pa.
Dresser Mfg. Div., 41 Fisher Ave., Bradford, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

COUPLINGS & CONNECTIONS, PIPE
James P. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

COUPLINGS, FLEXIBLE
Chain Belt Co., Milwaukee 1, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Link-Belt Co., Colmar, Pa.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

CULVERT PIPE
(See Pipe, Culvert)

CURB BOXES
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Kennedy Valve Mfg. Co., Elmira N. Y.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

DECHLORINATING EQUIPMENT AND CHEMICALS
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave., & 4th St., Philadelphia 33, Pa.
General Chemical Div. Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Box 178, Newark 1, New Jersey.

DE-MINERALIZATION EQUIPMENT (Water)
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, 303 S. Sixth St., Richmond, Va.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIATOMITE FILTER SEPTUMS
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Carborundum Co., Perth Amboy, N. J.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence, R. I.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES, TUBES AND FITTINGS
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Filtros Inc., East Rochester, N. Y.
Link-Belt Co., Colmar, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

DIGESTER EQUIPMENT (Sludge)
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hardinge Co., 240 Arch St., York, Pa.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columb 16, Ohio
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Process Engineers Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

DISTRIBUTORS (Sewage Filter)
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

DRAINS, GUTTER, FLOOR
Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.

DRILLING AND BORING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Johnson Gear and Mfg. Co., Ltd., 8th & Parker Sts., Berkeley 10, Calif.
Link-Belt Co., Colmar, Pa.
Payne Dean Co., Madison, Conn.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Worthington Corp., Harrison, N. J.

DRIVES, V-BELT
Link-Belt Co., Colmar, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Worthington Corp., Harrison, N. J.

DRYING SYSTEMS (Sludge)
R. D. Cole Mfg., Newnan, Ga.
Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Gen. Amer. Transp. Co., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link Belt Co., Colmar, Pa.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5.

EARTH MOVING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Link Belt Co., Colmar, Pa.

EJECTORS, PNEUMATIC or STEAM (For Sewage and Sludge)
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
H. D. Fowler Co., Inc., 901 Lane St., Seattle, Wash.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison N. J.

ELECTRICAL CONTROL EQUIPMENT
Electro Chemical Engr. & Mfg. Co., 758A Broad St., Emmaus, Pa.
The Foxboro Co., 38 Naponset Ave., Foxboro, Mass.
General Electric Corp., 1 River Road, Schnectady, N. Y.
Hays Corp., East 8th St., Michigan City 31, Ind.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Charles F. Warrick Co., 1964 W. Eleven Mile Road, Berkley, Mich.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNIT
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y. (Gasoline Engine Driven and Portable)
Westinghouse Electric Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

ENGINES DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Worthington Corp., Harrison, N. J.

ENGINES, DUAL FUEL
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Corp., Harrison, N. J.

ENGINES (Gas & Gasoline)
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Corp., Harrison, N. J.

ENGINES, SLUDGE GAS
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Worthington Corp., Harrison, N. J.

EXPANSON JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATNG
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment)

FEED WATER HEATERS AND FILTERS
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Worthington Corp., Harrison, N. J.

FENCE (Chain Link)
Continental Steel Corp., 1109 S. Main St., Kokomo, Ind.

FERRIC CHLORIDE
Dow Chemical Co., Midland, Mich.
Penn. Salt Mfg. Co., 100 Widener Bldg., Philadelphia 7, Pa. (Liquid)
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULPHATE
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Tennessee Corp., 617-29 Grant Bldg., Atlanta 1, Ga.

FIBRE PIPE
(See Pipe, Fibre)

FILTER AIDS
Johns-Manville Co., 22 E. 40th St., New York, N. Y.

FILTER ALUM
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Md.
Penn Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER EQUIPMENT
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
R. D. Cole Mfg., Newnan, Ga.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Municipal Service Co., 210 W. 10th St., Kansas City, Mo.
Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Walker Process Equip. Co., Aurora, Ill.
Worthington Corp., Harrison, N. J.

FILTER MEDIA
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Anthracite Equipment Co., Wilkes-Barre, Pa.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Carborundum Co., Perth Amboy, N. J.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.

FILTER PLATES AND TUBES
Carborundum Co., Perth Amboy, N. J.
Filtros, Inc., East Rochester, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER UNDERDRAINS, SEWAGE
American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Filtros, Inc., East Rochester, N. Y.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

FILTER UNDERDRAINS, WATER
American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
The Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Filtros, Inc., East Rochester, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nat'l. Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equipment, Inc., P. O. Box 266, Aurora, Ill.

FILTERS VACUUM
General American Process Equip. Div., Gen. Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
U. S. Hoffman Machinery Corp., 111 Fourth Ave., New York 3.
U. S. Stoneware Co., P. O. Box 350 Akron 9, Ohio.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia 42, Pa.

FITTINGS, PIPE, SOLDER TYPE
Alabama Pipe Co., Box 791, Anniston, Ala.
The American Brass Co., 25 Broadway, New York 4, New York.
Bethlehem Steel Co., Bethlehem, Pa.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Lock Joint Pipe Co., P. O. Box 269, E. Orange, N. J.

Johns-Manville Corp., 22 East 40th St., New York 16.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.
Yardley Plastic Co., 142 Parsons Ave., Columbus 15, Ohio.

FITTINGS, TEES, ELLS, ETC.

Alabama Pipe Co., P. O. Box, 791 Anniston, Ala.
American Cast Iron Pipe Co., 2930 N. 16th St., Birmingham 2, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Kraloy Plastic Pipe Co., Inc., 4710-20 E. Washington Blvd., Los Angeles 22, Calif.
McWane Cast Iron Pipe Co., P. O. Box 2601, Birmingham 2, Ala.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

FLASH MIXING EQUIPMENT

(See Mixers & Mixing Equipment.)

FLEXIBLE JOINTS

(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)

Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

FLOCCULATING EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes, Inc., 295 Madison Ave., New York 17, N. Y.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., Colmar, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

FLOORING

(See Gratings)

FLOW METERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hays Corp., East 8th St., Michigan City 31, Ind.
Leupold & Stevens Insts., Inc., 4445 N. E. Gibson St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia 42, Pa.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.

FLOW RECORDERS

(See Rate of Flow Recorders)

FLOW REGULATORS

(See Rate of Flow Controllers)

FLOW TUBES

(See Water Flow Tubes)

FLUMES, IRON & STEEL

Bethlehem Steel Co., Bethlehem, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FLUORIDATION CHEMICALS

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.
Phipps & Bird, Sixth & Byrd Sts., Richmond, Va.
Tennessee Corp., 1028 Connecticut Ave., N.W. 823-A, Washington, D. C.

FLUORIDATION EQUIPMENT

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave., & 4th St., Philadelphia 33, Pa.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Omega Machine Co., 345 Harris Ave., Providence, R. I.
Proportioneers, Inc., 350 Harris Ave., Providence, R. I.
Wallace & Tiernan, Box 178, Newark, N. J.

FOOT VALVE WITH STRAINER

(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS

Northrup & Co., Inc., Spring Valley, N. Y.

FURNACES (Melting, Pouring Ladles, Pots, Etc.)

Atlas Mineral Products Co., Mertztown, Pa.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Phipps & Bird, Sixth & Byrd Sts., Richmond, Va.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

GAGES (Liquid Level, Pressure Recording)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Infilco, Inc., P. O. Box 5033 Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.

GARBAGE GRINDERS

(See Grinders)

GAS DIFFUSERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Carborudum Co., Perth Amboy, N. J.
Filtros, Inc., East Rochester, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

GAS ENGINES

(See Engines, Gas)

GATES, FENCE (Steel)

Continental Steel Corp., Kokomo Ind.

GAS HOLDERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Company, 332 S. Michigan Ave., Chicago.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
The Dorr Company, Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hammond Iron Works, Warren, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

GAS INDICATOR AND DETECTORS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Hays Corp., East 8th St., Michigan City 31, Ind.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.

GATES, SHEAR

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.

GATES, SLUICE

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
R. D. Cole Mfg., Newnan, Ga.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
R.S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve and Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Inc., P. O. Box 388, Troy, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Payne Dean & Co., Madison, Conn.
A. P. Smith Mfg. Co., E. Orange, N. J.

GATE VALVES

(See Valves, Gate)

GEARS, SPEED REDUCING

De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., Colmar, Pa.
U. S. Electrical Motors, Ins., 200 E. Slauson Ave., Los Angeles 54, Calif.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

GEIGER COUNTERS

Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

GENERATORS (Electric)

Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
General Electric Co., 1 River Road, Schenectady, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES

(See Engine Generating Units)

GOOSENECKS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Worthington Corp., Harrison, N. J.

GRATINGS, FLOORING, TREADS

Irving Subway Grating Co., Inc., 50-89 27th St., Long Island City 1, N. Y.

GREEN SAND (See Zeolite)

Amer. Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.

Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar, New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee 1, Wis.
Dorr Co., Barry Place, Stamford, Conn.
General Electric Co. (household), 1 River Road, Schenectady 5, N. Y.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Link Belt Co., Colmar, Pa.
Walker Process Equipment, Inc., Aurora, Ill.
Westinghouse Elect. Corp. (household), Pittsburgh, Pa.
Worthington Corp., Harrison, N. J.

GRIT CHAMBER EQUIPMENT & GRIT WASHERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

GROUND KEY STOPS

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
The Ford Meter Box Co., Inc., Wabash, Ind.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
The Weisbach Corp., Kitson Valve Division, 1500 Walnut Street, Philadelphia 2, Pa.

GUNITING CONTRACTNG

Cement Gun Company, Inc., 1520 Walnut Street, Allentown, Pa.

HEATERS, DIGESTER

American Radiator & Standard Sanitary Corp., Box 1226, Pittsburgh 30, Pa.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

HOSE, STEAM, AIR, WATER, SUCTON

The American Brass Co., 25 Broadway, New York 4, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

HYDRANT PUMPS

(See Pumps, Hydrant)

HYDRANTS (Fire)

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Grinnell Co., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Ontario, Street, Troy, N. Y.
Ross Valve Mfg. Co., Inc., 4 Oakwood Ave., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

HYDRAULICALLY OPERATED GATE VALVES

(See Valves, Gate)

HYDROGEN ION EQUIPMENT

(See pH Test Equipment)

HYPO-CHLORINATORS

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Box 178, Newark 1, N. J.

HYPOCHLORITES (High Test)

(See Calcium Hypochlorite)

INCINERATORS (Sludge and Garbage)

Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 14, Minn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

INSECTICIDES

Dow Chemical Co., Midland, Mich.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Koppers Co., Koppers Bldg., Pittsburgh 19, Pa.

INSERTING SLEEVES, VALVE

James B. Clow, 201-209 N. Talman Ave., Chicago 80, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
M & H Valve & Fittings Co., Anniston, Ala.
A. P. Smith, 545 N. Arlington Ave., East Orange, N. J.

INSULATION

Barrett Div. Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Penna.

IRON SULFATE

(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS

Atlas Mineral Prod. Co., Mertztown, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Lake Chemical Co., 3052 W. Carroll Ave., Chicago 12, Ill.
Leadite Co., Philadelphia, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

JOINTS, EXPANSION—PIPE

James B. Clow, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
Johns-Manville Corp., 22 E. 40th Street, New York 16, N. Y.
Lock Joint Pipe Co., P. O. Box 269 East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

JOINTS, FLEXIBLE PIPE

Hamilton Kent Mfg. Co., Kent, Ohio.
James B. Clow & Sons, 201-299 N. N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

JOINTS, MECHANICAL FLEXIBLE

Amer. Brass Co., Waterbury, Conn.
H. Y. Carson Co., 1221 Pinsan St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
The A. P. Smith Mfg. Co., East Orange, New Jersey.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

LABORATORY APPARATUS, REAGENTS AND EQUIPMENT

Beckman Instruments, Inc., South Pasadena 1, Calif.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh, Pa.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Hays Corp., East 8th St., Michigan City 31, Ind.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Kewaunee Mfg. Corp., Adrian, Mich.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Lake Products Co., Inc., 1254 Grover Rd., St. Louis 23, Mo.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 57, Ill.

LEAD, CAULKING

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

LEAK LOCATING INSTRUMENTS

(See Water Leak Locating Instruments)

LINING, TANKS (See Tanks, Lining)

LIQUID CHLORINE

(See Chlorine, Liquid)

LOCATORS, BOX, PIPE AND VALVE

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Wilkinson Products Co., 3987 Chevy Chase Drive, Pasadena 3, Calif.

LUBRICANTS, VALVE

American Car and Foundry Co., Valve Div., 1501 Ferry Avenue East, Detroit, Mich.

MANHOLE FRAMES, COVERS

Alabama Pipe Co., Box 791, Anniston, Ala.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
R. D. Cole Mfg., Newnan, Ga.
Grinnell Co., 260 W. Exchange St., Providence 1, R. I.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

MANOMETERS

Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Company, Dept. 9F, Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Wallace and Tiernan, Newark 1, N. J.

METEOROLOGICAL INSTRUMENTS

Hays Corp., East 8th St., Michigan City 31, Ind.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Payne Dean and Co., Madison, Conn.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace and Tiernan, Newark 1, N. J.

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.

Alabama Pipe Co., Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201 N. Talman Drive, Chicago, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.
R. O. Wood Co., Public Ledger Bldg., Philadelphia 5, Pa.

METER CLEANING (Equipment and Chemicals)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
W. S. Darley & Co., 2810 Washington St., Chicago 12, Ill.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
General Chemical Div., Allied Chem. & Dye Corp., 40 Rector St., New York 6, N. Y.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Neptune Meter Co., 50 West 50th Street, New York 20, New York.

METER COUPLINGS & YOKES

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.
Worthington-Gamon Meter Division, Worthington Corp., 296 South St., Newark, N. J.

METER REPAIR PARTS

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Div., Worthington Corp., 296 South St., Newark 5, N. J.

METERS, ELECTRIC

General Electric Co., 1 River Road, Schenectady, N. Y.
Infilco Inc., 325 25th Pl., Chicago 16, Ill.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

METERS, FLOW TUBE

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

METERS, GAS

Bailey Meter Company, 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Fischer & Porter Co., Hatboro, Pa.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.

METERS (Turbine Type)

Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Sparling Meter Co., Box 3277 Los Angeles 54, Calif.

METER TESTING EQUIPMENT

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York City.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, VENTURI

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METERS, WATER (Consumer)

Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Buffalo Meter Co., 2917 Main St., Buffalo, N. Y.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Worthington-Gamon Meter Division, Worthington Corp., 296 South St., Newark, N. J.

MIXERS AND MIXING EQUIPMENT

(Chemical, Water and Sewage)

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., Milwaukee 1, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., Colmar, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equipment, Inc., P. O. Box 266, Aurora, Ill.
Worthington Corp., Harrison, N. J.

MOTORS, ELECTRIC

Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., 1 River Road, Schenectady, N. Y.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kansas.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

NOZZLES, FLOW

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

NOZZLES, SPRAY (Water and Sewage)

Chain Belt Co., Milwaukee 1, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., Colmar, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

OIL (Cutting and Threading)

Grinnell Co., 260 W. Exchange St., Providence 1, R. I.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.

OPERATING TABLES (Filter)

Amer. Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

ORIFICES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

OZONE EQUIPMENT

The Welsbach Corp., Ozone Processes Div., 1500 Walnut St., Philadelphia 2, Pa.

PACKING (Pumps and Valves)

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Kensley & Mattison Co., Ambler, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.

PAINT (Acid Resisting)

Atlas Mineral Prod. Co., Mertztown, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.

PENSTOCKS

Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York 20, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

pH TEST EQUIPMENT

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Beckman Instruments, Inc., So. Pasadena 1, Calif.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
The Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan, Newark 1, N. J.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 57, Ill.

PHOTOELECTRIC COLORIMETERS

Beckman Instruments, Inc., So. Pasadena 1, Calif.
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.

Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia, 44, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond 5, Va.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 51, Ill.

PIPE & FITTINGS, LINED

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

PIPE AND TANK COATINGS

Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.

PIPE, ASBESTOS-CEMENT

Johns-Manville Co., 22 E. 40th St., New York City.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Keasbey & Mattison Co., Ambler, Pa.

PIPE BENDING MACHINES (Hydraulic & Mechanical)

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Greenlee Tool Co., 2136 12th St., Rockford, Ill.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N. Y.

PIPE, CAST IRON

Alabama Pipe Co., Box 791 Anniston, Ala.
American Cast Iron Pipe Co., 2930 N. 16th St., Birmingham 2, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-299 No. Talman Ave., Chicago 12, Ill.
Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York 16, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
McWane Cast Iron Pipe Co., P.O. Box 2601, Birmingham, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE, CEMENT LINED

Alabama Pipe Co., P. O. Box 791, Anniston, Ala.
American Cast Iron Pipe Co., 2930 N. 16th St., Birmingham 2, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
McWane Cast Iron Pipe Co., P. O. Box 2601, Birmingham 2, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE, CEMENT LINING OF

Centriline Corp., 140 Cedar St., New York 6, N. Y.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Pipe Linings, Inc., 4675 Firestone Blvd., South Gate, Calif.
United States Pipe and Foundry Co., Burlington, N. J.

PIPE, CONCRETE, PRESSURE

American Concrete Pressure Pipe Assn, 228 N. LaSalle St., Chicago 1, Ill.
Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Price Bros. Co., P. O. Box 825, Dayton 1, Ohio.

PIPE, COPPER, BRASS AND BRONZE

The American Brass Co., 414 Meadow St., Waterbury 20, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Mueller Co., 512 Cerro Gordo St., Decatur, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE, CULVERT

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Continental Steel Corp., 1109 S. Main St., Kokomo, Ind.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, New York.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l. Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago, Ill.
Price Bros. Co., P. O. Box 825, Dayton 1, Ohio.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

PIPE CUTTING MACHINES

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Jos. G. Pollard Co., Inc., New Hyde Park, N. Y.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE DRILLS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N. Y.
The A. P. Smith Mfg. Co., East Orange, N. J.

PIPE ENAMELS, PROTECTIVE—COAL TAR

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.

PIPE FITTINGS (See Fittings)

PIPE, HARD RUBBER LINED (See Rubber Lined Pipe & Valves)

PIPE JOINT COMPOUNDS (See Jointing Compounds)

PIPE JOINT PACKING,

Atlas Mineral Products Co., Mertztown, Pa.
Electro Chemical Engr. & Mfg. Co., 758A Broad St., Emmaus, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Northrop & Company, Inc., Spring Valley, N. Y.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

PIPE JOINTS (Mechanical)

Alabama Pipe Co., Box 791, Anniston, Ala.
H. Y. Carson Co., 1221 Pinson St., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-209 N. Talman Ave., Chicago 80, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
McWane Cast Iron Pipe Co., P. O. Box 2601, Birmingham 2, Ala.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE JOINT TOOLS

Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., New Hyde Park, N. Y.

PIPE LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Wilkinson Products Co., 3987 Chevy Chase Drive, Pasadena 3, Calif.

PIPE, PLASTIC

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Carlon Products Corp., 10300 Meech Ave., Cleveland, Ohio.
Kralby Plastic Pipe Co., Inc., 4710-20 E. Washington Blvd., Los Angeles 22, Calif.
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.
Yardley Plastics Co., 142 Parsons Ave., Columbus 15, O.

PIPE, PUSHERS (Hydraulic)

Greenlee Tool Co., 2136 12th St., Rockford, Ill.

PIPE, SEWER

Bethlehem Steel Co., Bethlehem, Pa.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l. Clay Pipe Mfrs., 100 N. La Salle St., Chicago, Ill.
Price Bros. Co., P. O. Box 825, Dayton 1, Ohio.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL (All Types)

Bethlehem Steel Co., Bethlehem, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE TAPPING MACHINES

Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

PIPE TEST PLUGS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer Rod Equip. Co., 9059 Venice Blvd., Los Angeles, Calif.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE THAWING, ELECTRICAL, STEAM, FLAME

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Joseph G. Pollard Co., New Hyde Park, N. Y.

PIPE TOOLS, (Asbestos, Cement)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Keasbey & Mattison Co., Ambler, Pa.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Marlow Pumps, Ridgewood, N. J.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

PIPE, VITRIFIED CLAY

(See Vitrified Clay Pipe and Products.)

PIPE WRAPPING

Barrett Div. Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Johns-Manville Corp., 22 East 40th St., New York 16, N. Y.

PIPE, WROUGHT IRON

A. M. Byers Co., Box 1076, Pittsburgh, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 N. Exchange St., Providence 1, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Sonken-Galamba, 2nd & Riverview, Kansas City 18, Kan.

PITOT TUBES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PLASTIC PIPE & TUBING (See Pipe Plastic)

PNEUMATIC CONVEYORS
(See Conveyors & Conveying Equip.)

POROUS TUBES AND PLATES
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
Filtros, Inc., East Rochester, N. Y.

POWER TAKE-OFFS
(Truck Type)
Payne Dean Co., Madison, Conn.

PRESSURE REGULATORS
(See Regulators, Pressure)

PRESTRESSED CONCRETE TANKS
Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.

PROPORTIONING EQUIPMENT
(See Chemical Feed and Proportioning Equip.)

PUMPING CONTROLS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Barrett-Haentjens & Co., Hazleton, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.
Charles F. Warrick Co., 1964 W. Eleven Mile Road, Berkley, Mich.

PUMP PRIMERS
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
Marlow Pumps, Box 566, Ridgewood, N. J.

PUMPS, ACID-HANDLING
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.
Worthington Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
(See Pumps, Sump)

PUMPS, CENTRIFUGAL
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Homelite Corp., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Marlow Pumps, Box 566, Ridgewood, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

PUMPS, DEEP WELL
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tenn.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., Milwaukee 1, Wis.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps Inc., Box 566, Ridgewood, N. J.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Joseph G. Pollard Co., New Hyde Park, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Wallace & Tiernan, Box 178, Newark 1, N. J.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HYDRANT
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PUMPS, HYDRAULIC (Pressure Boosting)
Ross Valve Mfg. Co., Inc., 4 Oakwood Ave., Troy, N. Y.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 64, Calif.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St. Milwaukee 4, Wis.
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Marlow Pumps, Box 566, Ridgewood, N. J.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Worthington Corp., Harrison, N. J.

PUMPS, ROTARY
Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blv., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Layne & Bowler, Inc., P. O. Box 215 Hollywood Sta., Memphis 8, Tenn.
Manzel, Inc., 244 Babcock St., Buffalo, N. Y.
Marlow Pumps, Box 566, Ridgewood, N. J.
Worthington Corp., Harrison, N. J.

PUMPS, SEWAGE AND DRAINAGE
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Marlow Pumps, Box 566, Ridgewood, N. J.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Corp., Harrison, N. J.

PUMPS, SLUDGE
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pumps Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Fairbanks, Morse & Co., 658 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Marlow Pumps, Box 566, Ridgewood, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Worthington Corp., Harrison, N. J.

PUMPS, SUMP (AND CELLAR DRAINER)
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St. Aurora, Ill.
Byron Jackson Co., P.O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192, Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corporation, Port Chester, New York.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.

Marlow Pumps, Box 566, Ridgewood, N. J.
A. Y. McDonald Mf., Co., 12th Pine Sts., Dubuque, Iowa.
Worthington Corp., Harrison, N. J.

PUMPS, TURBINE

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
De Laval Steam Turbine Co., Nottingham Way, Tranton 2, N. J.
Deming Co., Salem, Ohio.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena, Calif.
Layne & Bowler, Inc., Box 6697 Hollywood Sta., Memphis 8, Tennessee.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Worthington Corp., Harrison, N. J.

PUMPS, VACUUM

Chicago Pump Co., 622 Diversey Pkwy., Chicago 14, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Economy Pumps, Inc., 19th & Lehigh, Philadelphia 32, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 51, Ill.
Worthington Corp., Harrison, N. J.

RAIN GAGES (See Meteorological Instruments)

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Bulkley Dunton Processes, Inc., 295 Madison Ave., New York 17, N. Y.
Fischer & Porter Company, 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 4, Minnesota.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Insts., Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

REAMERS

Mueller Co., Decatur 70, Ill.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE (Water and Gas)

American Radiator Co., Bessemer Bldg., Pittsburg, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
The Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh.
Hays Corp., East 8th St., Michigan City 31, Ind.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 4, Minnesota.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

RESERVOIRS, STEEL (See Tanks & Standpipes)

RESIDUAL CHLORINE CONTROLLERS

Wallace & Tiernan Co., Newark, N. J.

RESIDUAL CHLORINE TEST APPARATUS

Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Preportioners, Inc., 350 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace and Tiernan, Box 178, Newark 1, New Jersey.

ROOF COATINGS

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Darling Valve & Mfg. Co., Williamsport, Pa.
Electro Chemical Engr. & Mfg. Co., 758 A Broad St., Emmaus, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.

RUBBER PACKING GASKETS

Atlas Mineral Products Co., Mertztown, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Il.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Northrop & Co., Spring Valley, N. Y.
U. S. Stoneware Co., P. O. Box 350, Akron, Ohio.

RUST PREVENTION (Water Treatment)

Calgon, Inc., Hagan Bldg., 325 4th Ave., Pittsburgh, Pa.
Electro Rust-Proofing Corp., (N. J.), Belleville 9, N. J.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Solvay Process Div., Allied Chemical & Dye Corp., 61 Broadway, New York 6, N. Y.

SADDLES, PIPE

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Brandford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Kraloy Plastic Pipe Co., Inc., 4710-20 E. Washington Blvd., Los Angeles 22, Calif.
Mueller Co., Decatur 70, Ill.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SAMPLERS AND SAMPLING TABLES

Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Hardinge Co., Inc., 240 Arch St., York, Pa.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Phipps & Bird, Sixth & Byrd Sts., Richmond, Va.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Infilco, Inc., Tuscon, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

SCALES, SLUDGE CONVEYOR

Builders-Providence., Inc.,350 Harris Ave., Providence 1, R. I.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace & Tiernan, Belleville 9, N. J.

SCREENING AND COMMINUTING (See Comminuting Devices)

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., Milwaukee 1, Wis.
Link-Belt Co., Colmar, Pa.
Newport News Shipbuilding & Dry Dock Co., Newport News, Va.

SCREENS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 2084), Seattle, Wash.
Infilco, Inc., Tuscon, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Newport News Shipbuilding & Dry Dock Co., Newport News, Va.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip. Co., P. O. Box 266, Aurora, Ill.

SCREENS, VIBRATING

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Syntron Co., 650 Lexington. Homer City, Pa.

SCREEN, WATER WELL

Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tennessee.

SCUM REMOVERS

(See Clarifiers.)

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Infilco, Inc., Tuscon, Ariz.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.

SERVICE BOXES (Water)

Alabama Pipe Co., Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
James B. Clow & Sons., 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.

Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps & Bird, Inc., 308 S. 6th St., Richmond 5, Va.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SEWAGE SLUDGE DRYERS
(See Drying Systems, Sludge)

SEWAGE SLUDGE INCINERATOR
(See Incinerators)

SEWER CLEANING EQUIP. AND SERVICE
Ace Pipe Cleaning Contractors, Inc., 3513 East 18th St., Kansas City 1, Mo.
Bucyrus-Erie Co., South Milwaukee, Wis.
Champion Corp., 4714 Sheffield Ave., Hammond, Ind.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Expanding Sewer Machine Co., 108 E. Walnut St., Nappanee, Ind.
J. C. Fitzgerald, P. O. Box 289, Coral Gables 34, Fla.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Rootes Motors, Inc., 27-11 Bridge Plaza Rd., Long Island City, N. Y.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER PIPE
(See Pipe, Sewer.)

SEWER PIPE JOINTS (and Jointing Compounds)
Atlas Mineral Prod. Co., Mertztown, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York 7, N. Y.
Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.
National Clay Pipe Manufacturers, Inc., 100 North LaSalle St., Chicago 2, Illinois.
Northrop & Company, Inc., Spring Valley, N. Y.

SEWER RODS
Champion Corp., 4714 Sheffield Ave., Hammond, Ind.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Expanding Sewer Machine Co., 108 E. Walnut St., Nappanee, Ind.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SIPHONS (Sewage Dosing)
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Rootes Motors, Inc., 27-11 Bridge Plaza Rd., Long Island City, N. Y.

SLEEVES, PIPE REPAIR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 41 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., 512 Cerro Gordo St., Decatur, Ill.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

SLEEVES, TAPPING (Valve)
Eddy Valve Co., Waterford, N. Y.
Darling Valve & Manufacturing Co., Williamsport, Penna.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

SLUDGE COLLECTORS
American Well Works, 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes, Inc., 295 Madison Ave., New York 17, N. Y.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., Milwaukee 1, Wis.
Chicago Pump Co., 622 Diversey Pkwy, Chicago 14, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., Colmar, Pa.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

SLUDGE DISINTEGRATORS
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Gruendler Crusher & Pulv. Co., 2915 N. Market St., St. Louis 6, Mo.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE DRYERS
(See Drying Systems)

SLUDGE EJECTORS
(See Ejectors, Pneumatic.)

SLUDGE GAS ENGINES
(See Engines, Sludge Gas)

SLUDGE INCINERATORS
(See Incinerators)

SLUDGE PUMPS
(See Pumps, Sludge)

SLUDGE SAMPLERS
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SLUDGE VALVES (Telescopic)
American Well Works, 100 N. Broadway, Aurora, Ill.
Link Belt Co., Colmar, Pa.

SODA ASH
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
Mathieson Industrial Chemical Co., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Solvay Process Div., Allied Chemical & Dye Corporation, 61 Broadway, New York 6, N. Y.

SODIUM BISULPHITE
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SODIUM CHLORITE
Mathieson Industrial Chemical Co., Matnieson Bldg., Baltimore 3, Maryland.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SODIUM HYPOCHLORITE
John Wiley Jones Co., 100 Sunny Sol Blvd., Caledonia, N. Y.

SODIUM PHOSPHATES (Glassy)
Blockson Chemical Co., P. O. Box 1407, Joliet, Illinois.
Calgon, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 22, Pa.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Phipps & Bird, 303 S. Sixth St., Richmond, Va.

SODIUM SILICATE
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Phipps & Bird, 303 S. Sixth St., Richmond, Va.

SOFTENERS
(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Worthington Corp, Harrison, N. J.

SPRINKLING FILTER EQUIP.
(See Trickling Filter Equip.)

SPRINKLING FILTER UNDERDRAINS
(See Filter Underdrains, Sewage.)

STACKS
(Steel and Wrought Iron)
A. M. Byers Co., Box 1076, Pittsburgh, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.

STANDPIPES
(See Tanks and Standpipes.)

STERILIZING WATER MAINS
(See Water Main Sterilization)

STIRRERS (Laboratory)
Omega Machine Co., 345 Harris Avenue, Providence 1, Rhode Island.
Phipps & Bird, Inc., 303 S. 6th St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wilkens Anderson Co., 4525 W. Division St., Chicago 57, Il.

STOKERS
Combustion Engineering-Superheater, Inc., 200 Madison Ave., New York, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., Pittsburgh 30, Pa.

STRAINERS, SUCTION
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
R.-S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.

SULPHATE OF ALUMINA
(See Filter Alum)

SULPHUR DIOXIDE (Liquid)
Tennessee Corp., 617-29 Grant Bldg., Atlanta 1, Ga.

SWITCHBOARD & SWITCH GEAR
Electric Mach. Mfg. Co., 800 Central Ave., Minneapolis 13, Minn.
General Electric Co., 1 River Road, Schnectady, N. Y.
Westinghouse Electric Mfg. Co., Pittsburgh 30, Pa.

TANK LININGS
Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich.
U. S. Stoneware Co., P. O. Box 350, Arkan 9, Ohio

TANK MAINTENANCE & REPAIR
Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.
Dixie Tank & Bridge Co., P. O. Box 14, Memphis 1, Tenn.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York, N. Y.
Speelmon Elevated Tank Service, 822 N. Court St., Rockford, Ill.

TANKS AND STANDPIPES (Steel)
Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Bethlehem Steel Co., Bethlehem, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York 20, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Stoneware Co., Akron 9, Ohio.

TANKS, RUBBER LINED
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.

Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Hammond Iron Works, 630 Fifth Ave., New York 20, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.

TAPPING MACHINES

Glauber Brass, Inc., Kinsman, Ohio.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

TASTE & ODOR REMOVAL CHEMICALS

Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 250 Park Ave., New York 17, N. Y.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Mathieson Industrial Chemical Co., Baltimore 3, Maryland.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Welsbach Corp., Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

TESTERS (Water Meter)

Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

THICKENERS (Sludge)

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Dorr Co., Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Link Belt Co., Colmar, Pa.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

TOOLS, PIPE

(See Pipe Tools)

TOOLS, PNEUMATIC

Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Worthington Corp., Harrison, N. J.

TRACTORS, BULLDOZERS, Etc.

Bucyrus-Erie Co., South Milwaukee, Wis.

TRANSFORMERS, ELECTRIC

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Westinghouse Electric Corp., Pittsburgh, Pa.

TRAPS, DRIP, FLAME, SEDIMENT, STEAM

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.

TRENCHING EQUIPMENT

Bucyrus-Erie Co., South Milwaukee, Wis.

TRICKLING FILTER EQUIPMENT

American Well Wks., 100 N. Broadway, Aurora, Ill.
Bulkley Dunton Processes Inc., 295 Madison Ave., New York 17, N. Y.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Avenue, Chicago 13, Illinois.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

TRICKLING FILTER UNDERDRAINS

(See Filter Underdrains)

TURBIDIMETERS

General Electric Co., 1 River Road, Schenectady 5, N. Y.
Hellige, Inc., 877 Stewart Ave., Garden City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wilkens-Anderson Co., 4525 W. Division St., Chicago 57, Ill.

TURBINES, HYDRAULIC

De Laval Steam Turbine Co., Trenton, N. J.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.

TURBINES, STEAM

De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Westinghouse Elect. Corp., Pittsburg 30, Pa.
Worthington Corp., Harrison, N. J.

VACUUM FILTERS

Oliver United Filters, Inc., 33 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
U. S. Hoffman Machinery Corp., 111 Fourth Ave., New York 3, N. Y.
U. S. Stoneware Co., P. O. Box 350, Akron 9, Ohio.

VALVE BOXES

Alabama Pipe Co., Box 791, Anniston, Ala.
Art Concrete Works, 366 S. Fair Oaks Ave., Pasadena, Calif.
Chapman Valve Mfg., Indian Orchard, Mass.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

VALVE BOX LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Globe Phone Mfg. Co., 2 Linden St., Reading, Mass.
Joseph G. Pollard Co., New Hyde Park, N. Y.

VALVE INSERTING MACHINES

Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

VALVE OPERATOR

(See Gate Valve Operator)

VALVE VAULT COVERS

E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

VALVES, AIR RELEASE & VACUUM BREAKING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N.Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Iowa Valve Co., 201 N. Talman Ave., Chicago, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Inc., P. O. Box 388, Troy, N. Y.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
Rockwell Mfg. Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

VALVES, ALTITUDE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.

VALVES, BUTTERFLY

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Crane Co., 836 S. Mich. Ave., Chicago 5, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Pelton Water Wheel Co., 2929 19th St., San Francisco, Calif.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S. Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.

VALVES, CHECK

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hersey Mfg. Co., South Boston 27, Mass.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio.
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.

VALVES, CHLORINE

Amer. Car and Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
Wallace and Tiernan, Newark 1, New Jersey.

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

VALVES, DIAPHRAGM

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

VALVES, FLAP

Chapman Valve Mfg. Co., Indian Orchard, Mass.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Morse Bros. Mach. Co., 2900 Brighton Blvd., Denver, Colo.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, FLOAT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Ave., Philadelphia 44, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FOUR WAY

American Water Softener Co., Philadelphia 33, Pa.
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
DeZurik Shower Co., Sartell, Minn.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
R-S Products Corp, 4600 Germantown Ave., Philadelphia 44, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
DeZurik Shower Co., Sartell, Minn.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 East Becher St., Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Rensselaer Valve Company, Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, LUBRICATED PLUG

American Car and Foundry Co., Valve Division, 1501 Ferry Avenue East, Detroit, Michigan.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
R-S Products Corp, 4600 Germantown Ave., Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

VALVES MECHANICAL JOINT

Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Iowa Valve Co., 201 N. Talman St., Chicago, Ill.
Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M & H Valve & Fitting Co., Anniston, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.
R. D. Wood Co., Public Ledger Bldg., Philadelphia 5, Pa.

VALVES, MOTOR OPERATED

American Car & Fdy. Co., Valve Div., 1501 E. Ferry Ave., Detroit 11, Mich.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., P. O. Box 931, Elmira, N. Y.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Payne Dean and Co., Madison, Conn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, MUD AND PLUG

American Car & Fdy. Co., Valve Div., 1501 E. Ferry Ave., Detroit 11, Mich.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
DeZurik Shower Co., Sartell, Minn.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
Rockwell Mfg. Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, PRESSURE REDUCING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kans.

VALVES, RELIEF

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., P. O. Box 388, Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.

Neptune Meter Co., 50 West 50th St., N. Y. 20.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
Welsbach Corp., Kitson Valve Div., 1500 Walnut St., Philadelphia 2, Pa.

VALVES (Rubber, Plastic, Glass or Lead)

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Mfg. Co., Williamsport, Penna.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.
U. S. Stoneware Co., Akron 9, Ohio.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)

American Car & Fdy., Valve Div., 1501 E. Ferry Ave., Detroit 11, Mich.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Fischer & Porter Co., 925 Warminster Rd., Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 2075 Keenan Bldg., Pittsburgh 22, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1936 E. Water St., Elmira, N. Y.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
W. S. Rockwell Co., 2763 Eliot St., Fairfield, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., 500 Lincoln St., York, Pa.
A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., South Boston 27, Mass.
Kennedy Valve Mfg. Co., P. O. Box 981, Elmira, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

VARIABLE SPEED TRANSMISSIONS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Link Belt Co., Colmar, Pa.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Worthington Corp., Harrison, N. J.

VENTURI TUBES

American Water Softener Co., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

VIBRATING SCREENS (Liquid)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link Belt Co., Colmar, Pa.

VISES, PIPE

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
The Ridge Tool Co., 400 Clark Street, Elyria, Ohio.

VITRIFIED CLAY PIPE AND PRODUCTS

Nat'l. Clay Pipe Mfrs., Inc., 100 N. La Salle St., Chicago 2, Ill.
U. S. Stoneware Co., Box 350, Akron 9, Ohio.

WASTE GAS BURNERS

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagents)

WATER HAMMER ARRESTERS

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Pelton Water Wheel Co., 2929 19th St., San Francisco 10, Calif.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

WATER LEAK, LOCATING INSTRUMENTS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
Joseph H. Pollard Co., Inc., New Hyde Park, N. Y.
Wilkinson Products Co., 3987 Chevy Chase Drive, Pasadena 3, Calif.

WATER LEVEL CONTROL

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Hays Corp., East 8th St., Michigan City 31, Ind.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco., Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan, Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Pike Hoffman Control Co., 272 E. 5th St., St. Paul 1, Minn.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Smith & Loveless, Inc., 3427 Broadway, Kansas City, Mo.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
Charles F. Warrick Co., 1964 W. Eleven Mile Road, Berkley, Mich.

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., East 8th St., Michigan City 31, Ind.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Inc., Box 3277, Los Angeles 54, Calif.

WATER MAIN CLEANING

Ace Pipe Cleaning Contractors, Inc., 2003 Indiana Ave., Kansas City 1, Mo.
Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.

WATER MAIN PACKING GASKETS

Atlas Mineral Products Co., Mertztown, Pa.
Johns-Manville Corp., 22 East 40th Street, New York 16, New York.
Northrop & Co., Spring Valley, N. Y.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Inertol Co., Newark 5, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
U. S. Stoneware Co., Box 350, Akron 9, Ohio.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Water Seals Inc., 9 S. Clinton St., Chicago 6, Ill.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT

American Water Softener Co., Inc., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
R. B. Carter, 192 Atlantic Ave., Hackensack, N.J.
Chain Belt Co., Milwaukee 1, Wis.
Dorr Co., Inc., Barry Place, Stamford, Conn.
Hills McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Koppers Co., Koppers Bldg., Pittsburgh 19, Pa.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2412 W. Carson St., Pittsburgh 4, Pa.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Process Engineers, Inc., 6381 Hollywood Blvd., Los Angeles 28, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Solvay Process Div., Allied Chemical & Dye Corporation, 61 Broadway, New York 6, N. Y.
Walker Process Equip., Inc., P. O. Box 266, Aurora, Ill.
Worthington Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER SUPPLY CONTRACTORS

(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION

Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh 22, Pa.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Proportioneers, Inc., 350 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Worthington Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WEED KILLERS

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dow Chemical Co., Midland, Mich.
General Chemical Division, Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

WELL CLEANING CHEMICALS

Calgon, Inc., 323 4th Ave., Pittsburgh 22, Pa.
General Chemical Division, Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

WELLS, COMPLETE

Layne & Bowler, Inc., Box 6697, Hollywood Sta., Memphis 8, Tennessee.
Ranney Method Water Supplies, Inc., P. O. Box 277, Columbus 9, Ohio

WRAPPING, PIPE

(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.

WROUGHT IRON

(Pipe, Gates, Bars, Weirs, etc.)
A. M. Byers Co., Box 1076, Pittsburgh, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

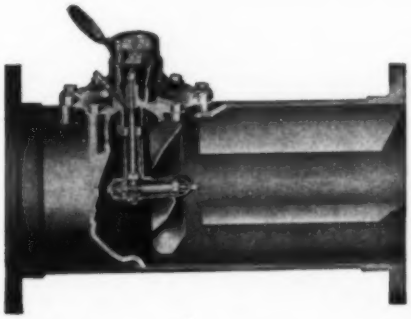
American Water Softener Co., S. E. Cor. Lehigh Ave. & 4th St., Philadelphia 33, Pa.
Infilco, Inc., P. O. Box 5033, Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Permutit Co., 330 W. 42nd St., New York 36, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

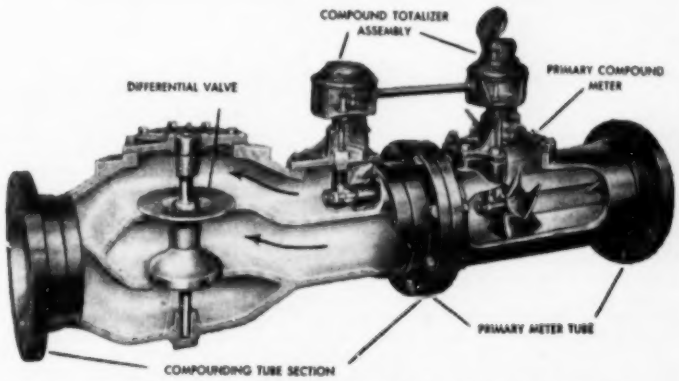
SPARLING METER COMPANY
INCORPORATED

LOS ANGELES 54.....Box 3277
CHICAGO 8.....1500 South Western Ave.
BOSTON 8.....6 Beacon Street
DALLAS 1....726 Reserve Loan Life Bldg.

626 Broadway.....CINCINNATI 2
101 Park Avenue.....NEW YORK 17
1932 First Avenue.....SEATTLE 1
66 Luckie Street N. W.....ATLANTA 3

KANSAS CITY 6, MO.....6 East 11th St.





TOTALIZATION is the primary step in all Sparling Main Line Meters. Accuracy at rated ranges is guaranteed within 2 per cent, and pressure drop is negligible!

SPARLING Meters are *complete* Totalizing units, installed as easily as a length of the pipe itself. They can be mounted on the suction or the discharge side of pump.

The Compound meters are installed horizontally, but the tube and saddle type Sparling Meters may be installed horizontally, vertically, or on an angle.

Registration is in any quantity unit desired.

Accurate knowledge of main-line flows is a vital factor in Water Works economy! The Sparling Meter is easily installed at moderate cost for consistently accurate measurement, with very little maintenance. Every Sparling Meter is triple-tested, throughout its rated range.

COMPOUND Meters for Mains 6-inch to 36-inch

Consistent accuracy over flow-range as wide as 1-to-125

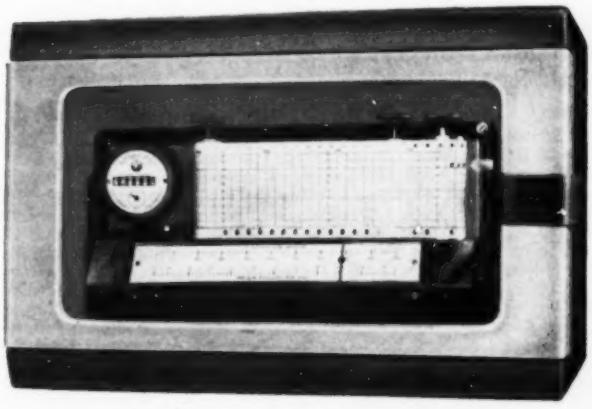
Differential valve cracks at about one pound per square inch back pressure from the smaller meter. The smaller meter measures all flows below the minimum accurate range of the larger meter. Both meters drive through ratchet clutches to a common totalizer, which thus operates with the faster turning meter.

•

FLANGED TUBES—2-inch to 36-inch
SCREW TUBES—2-inch to 6-inch
BELL & SPIGOT—4-inch to 36-inch
SADDLE-MOUNTED—6-inch to 72-inch

INDICATORS • RECORDERS
TOTALIZERS • CONTROLS

Flow-rate indicators and recorders are available for use with Sparling Meters if, as and when required. The mercury-governor type, with circular charts for 24-hour or 7-day records, are mechanically controlled within 15 feet of the meter, or electrically controlled at any distance.



Type 225, shown at right, electric remote controlled, is actuated by differential mechanism to indicate and record 1 to 33 range of flows.

Choice of Pedestal, Wall or Panel mounted.

The Striptograph, shown at left, has a straight-reading 60-day strip roll chart. Indicator scale is calibrated in two flow equivalents. Operated by electric remote control.

Mechanical or electric controls for auto-metered chemical feed are available.

Bulletin 313 comes upon request

WATER AND SEWAGE WORKS INFORMATION

Where to Find It

LINN H. ENSLOW
Editor
"Water & Sewage Works"

LIST NO. 1—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
American Civil Engineering Handbook—5th Ed. ($9.00)	John Wiley & Sons, New York City	Merriman & Wiggin
A.W.W.A. Recommended Practices and Specifications	Am. Water Works Assn., New York City	
Individual Reprints (Nominal prices)		
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Census of Water Treatment Plants	Am. Water Works Assn., New York City	
Chlorine Manual (F)	The Chlorine Institute, New York 17, N.Y.	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Copper Sulfate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Elements of Water Supply Engineering (2nd Ed.) ($4.00)	John Wiley & Sons, New York City	Waterman
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Handbook of Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Hydraulic Tables—3rd Ed. ($2.50)	John Wiley & Sons, New York City	Williams & Hazen
Lab. Manual—Water and Sewage Anal., 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge, Mallman
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co., Brooklyn 2, N. Y.	A. A. Hirsch
Manual for Water Works Operators ($3.00)	Texas Water and Sewage Works Assn., c/o State Dept. Health, Austin, Tex.	
Manual of Recommended Water Sanitation Practice (15c)	U.S. Govt. Printing Office, Washington, D.C.	
Manual of Wtr. Quality and Treatment—2nd Ed. ($4.50)	Am. Water Works Assn., New York City	
Manual of Water Works Accounting ($4.00)	Am. Water Works Assn., New York City	
Microscopy of Drinking Water (4th Ed. $7.50)	John Wiley & Sons, New York City	Whipple-Fair
pH Control (F)	W. A. Taylor Co., Baltimore, Md.	
Plane Surveying ($5.50)	John Wiley & Sons, New York City	Tracy
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Public Water Supplies—4th Ed. ($6.50)	John Wiley & Sons, New York City	Turneaure & Russell
Reference Bibliography for Water and Sewage Works	Gilbert Associates, Inc., Reading, Pa.	
Stand. Meth. of Wtr. and Sewage Anal., 9th Ed. ($4.00)	A. P. H. A. and A. W. W. A., New York City	Various
Taste and Odor Control in Water Purification (F)	Industrial Chem. Sales Div., New York 17, N. Y.	
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Purification ($7.00)	McGraw-Hill Co., New York City	Ellms
Water Purification Control, 3rd Edition	Williams & Wilkins, Baltimore, Md.	Hopkins
Water Purification for Plant Operators ($2.50)	McGraw-Hill Co., New York City	Norcom and Brown
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	
Water Supply & Treatment, 3rd Ed. ($0.75)	National Lime Assn., Washington, D. C.	Hoover
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Treatment and Purification 2nd Ed. ($2.75)	McGraw-Hill Co., New York City	Ryan
Water Works Engineering in Disaster (F)	O.C.D. Pub. No. 2022, Washington, D. C.	McCallum
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert

(F) Available as Free Publication at this writing.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Applied Hydraulics ($7.50)	John Wiley & Sons, Inc., New York City	Addison
Bibliography on Water & Sewage Analysis	Ga. Inst. Tech., Atlanta, Ga.	Weil, Murray & Reid
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Civil Engineering Handbook—3rd Ed. ($10.00)	McGraw-Hill Co., New York City	Urquhart
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Corrosion; Causes and Prevention ($7.00)	John Wiley & Sons, Inc., New York City	Uhlig
Corrosion Handbook ($12.00)	McGraw-Hill Co., New York City	Speller
Data Book on Design for Civil Engineers (3 Vols.)	John Wiley & Sons, Inc., New York City	Elwyn E. Seelye
Deep Well Drilling	The Gulf Publishing Co., Houston, Tex.	Walter & Jeffery
Design of Dams ($5.00)	McGraw-Hill Book Co., New York City	Hanna and Kennedy
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Financial Administration of Municipal Utilities ($3.75)	Public Administration Service	Tenner
Fresh Water Biology ($8.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Geomorphology	McGraw-Hill Book Co., Inc., New York City	A. K. Lobeck
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS (Con't.)

Books	*Publishers*	*Authors*
Ground Water, Its Development, Uses & Conservation	Edward E. Johnson, Inc., St. Paul, Minn.	Bennison
Guiding Principles of Public Service Reg. (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Handbook of Applied Hydraulics ($7.50)	McGraw-Hill Co., New York City	Davis
Hydraulics 5th Ed. ($4.00)	McGraw-Hill Co., New York City	King
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
Laboratory Control of Water Purification ($4.00)	Case, Sheppard, Mann Pub. Co., New York 18, N. Y.	Cox
Mechanical Engineers' Handbook—11th Ed. ($6.00)	John Wiley & Sons, New York City	Kent
pH and Its Practical Application ($3.50)	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Physics of the Earth IX	McGraw-Hill Book Co., Inc., New York City	Oscar E. Meinzer
Plumbing Engineering ($3.50)	Pittman Publishing Co., New York	Cleverdon
Pocket Companion (nominal)	Carnegie-Steel Corp., New York City	
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Pump Handbook	National Press, Millbrae, Calif.	Finch
Rainfall and Runoff ($9.00)	MacMillan Co., New York City	Foster
Rates and Rate Structure	Ohio State Univ., Columbus, O.	Jt. Comm. ABA, ASCE, AWWA, FISWA
Standards of Hydraulic Institute—8th Ed. ($3.00)	Hydraulic Institute, New York 6, N. Y.	
Standard Practices for Stationary Diesel Engines ($2.50)	Diesel Engine Mfg. Assn., Chicago, Ill.	
Summary of Census Data on Water Treatment Plants in the United States (Reprint)	Am. Water Works Assn., New York City	U. S. Pub. Health Service
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
The Hardy Cross Method of Distribution System Design	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
The Quest for Pure Water ($5.00)	Am. Water Wks. Assn., New York City	Baker
Valve Manual ($2.00)	Mo. Water & Sew. Conf.	Lischer
Water Bacteriology—6th Ed. ($4.50)	John Wiley & Sons, New York City	Prescott, Winslow & McCrady
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Assn., New York City	Wolman & Gorman
Water Quality & Treatment—2nd Ed. ($5.00)	Am. Water Works Assn., New York City	Various
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (4th Ed. $6.50)	McGraw-Hill Co., New York City	Babbitt & Doland
Water Supply Paper No. 658 (Quality of Waters)	U. S. Geological Survey, Washington, D. C.	Stabler

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Chemical Treatment of Sewage (nominal)	Am. Public Health Assn., New York City	Committee Report
Chlorine Manual (F)	The Chlorine Institute, New York 17, N. Y.	
Federation of Sewage & Indus. Wastes Assns. Manuals of Practice (Nominal):	Champaign, Ill.	Various
Chlorination of Sewage and Industrial Wastes		
Municipal Sewer Ordinances		
Occupational Hazards in Operation of Sewage Works		
Utilization of Sewage Sludge as Fertilizer		
Lab. Manual of Water and Sewage Anal. 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Manual for Sewage Plant Operators ($3.50)	Texas Water & Sewage Wks. Assn., c/o State Dept. of Health	
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Principles of Sewage Treatment ($0.50)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Reference Bibliography for Water and Sewage	Gilbert Associates, Inc., Reading, Pa.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Sewage Treatment ($3.50)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Sewerage and Sewage Disposal Textbook ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Stand. Meth. of Water and Sewage Analysis, 9th Ed. ($4.00)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.

LIST NO. 4—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge
Modern Sewage Disposal ($3.50)	Federation of Sewage and Indus. Wastes Assns., Champaign, Ill.	Various
Municipal and Rural Sanitation, 3rd Ed.	McGraw-Hill Book Co., Inc., New York City	Ehlers & Steel
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Rates and Rate Structures	Ohio State Univ., Columbus, O.	Jt. Comm. ABA, ASCE, AWWA, FISWA
Sewage Trade Waste Treatment	Govt. Printer, Adelaide, Australia	Henry J. N. Hodgson
Sewerage and Sewage Treatment—2nd Ed. ($4.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage and Sewage Treatment—6th Ed. ($6.50)	John Wiley & Sons, New York City	Babbitt
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Stream Sanitation ($3.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	

(F) Available as Free Publication at this writing.

***Note*—Sewage works men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the handbooks.

LEGAL PROBLEMS CONFRONTING WATER WORKS MANAGEMENT*

By JOHN H. MURDOCH JR.

Vice Pres. and Counsel
Am. Water Works Service Co., Inc.
Philadelphia, Pa.

TO keep this paper within tolerable length, consideration of many interesting legal problems must be omitted entirely and the answers to some of those studied must be indicated by statements of general legal principles applicable to a wide variety of factual situations. Two subjects will be discussed [1] water works liability for damages caused by negligent operation; [2] weighing the public interest in water supply against property rights. Usually the term "water works" will be applied, without distinction, to both publicly and privately owned systems, and will mean an enterprise offering public water supply service.

Water Works Liability

In the law of negligence there are certain words and phrases which are used so often that a knowledge of their meaning is essential to an understanding of the statements of legal principles in which they are used. The first word to be defined is "negligence." Negligence is the failure to observe, for the protection of the interests of another person, that degree of care, precaution, and vigilance which the circumstances justly demand, whereby such other person suffers injury. Negligence is the absence or want of care which a reasonable man would exercise under the circumstances (*Materna* v. *Pennsylvania Railroad* 358 Pa. 149). Any conduct which falls below the standard established by law for the protection of others against unreasonable risk of harm is negligence.

This definition of negligence in turn calls for a definition of the phrase "standard of conduct established by law." It means such course of conduct as would be followed by a reasonable man under like circumstances. Who is a reasonable man? He is a person exercising those qualities of attention, knowledge, intelligence, and judgment which society requires of its members for the protection of their own interests and the interests of others. Negligent conduct may be either: [1] a failure to do an act which is necessary for the protection or assistance of another and which the actor has a duty to do; or [2] an act which the actor as a reasonable man should realize involves an unreasonable risk of causing an invasion of an interest of another.

The last definition can be understood only if "unreasonable risk" is defined. It means a risk which outweighs the values attached to the conduct which involves it. "The operation of railways and other public utilities, no matter how carefully carried on, produces accidents which kill or harm many people, but the risk involved in the operation is more than counterbalanced by the service which they render to the public" (Restatement of the Law, Torts, Section 292). Because of this counterbalance in favor of the operation, it is not an unreasonable risk which is involved. On the other hand, driving a car at 50 mph through a business street during the rush hour on a mere pleasure trip would be conduct involving an unreasonable risk of harm to others. The pleasure trip at that time, place, and rate of speed does not have enough social value to counterbalance the dangers involved.

In theory it is probable that all conduct involves risk, but a reasonable man need weigh only those circumstances which he knows or should know at the time of his action. A reasonable man is not assumed to be all seeing, all knowing or clairvoyant. He need not refrain from conduct having social value because he fears there may be evil consequences traceable to elements in the circumstances which he does not know or could not know through the exercise of reasonable prudence.

Water Works Risks

In water works enterprises, the standard of conduct established by law is the course of conduct which would be recognized by good water works operators—considered as such by this Association—to be the course of action which should be followed by a fellow water works operator under the circumstances. A water works operator is negligent when he fails to act or when he acts in a way which does not measure up to what well-grounded, careful, considerate, but active water works operators think should be proper action. Particular attention is directed to the definition of unreasonable risk as "a risk which outweighs the value attached to the conduct which involves it."

Many water works operations involve elements of risk, but if the community considers that the social value of the operation outweighs the risk of harm, then water works operators are not guilty of imposing and unreasonable risk on others by carrying on those operations. The water works is liable for damages only if water works action caused the damage and if the action involved an unreasonable risk. Thus, a high-pressure water line in a business street may burst. There is, therefore, a risk in placing such a line in such a place, but the community needs that line in that street and the utility of having the line there—its social value—outweighs the risk of harm. The act of placing the lines does not impose an unreasonable risk. If, despite the fact that the line was properly installed and the pipe was of proper class for the conditions, it bursts and floods adjacent basements, there is no negligence and no liability for damages. On the other hand, if the line was improperly laid on an unsound and unstable foundation and injury is caused by a resulting break and flood, then damages could be collected because the lack of care in laying was an act which imposed an unreasonable risk and was not up to the standard of a reasonable man.

The same legal principles are involved in passing upon questions of liability in other features of water works enterprises. If a water works operator knows, or by the exercise of reasonable care should know, of dangerous conditions and fails to correct them, the water works would be liable for damages to one injured if the injury was caused by the dangerous condition. Broken, sunken, or protruding valve box or meter box covers are typical examples. Slight irregularities in a pavement resulting from such box covers can probably never be avoided, and would probably be held not to impose an unreasonable risk on pedestrians or drivers, but an irregularity which is so pronounced as to make injuries a probability and which has existed for a substantial length of time so that the water works men should have seen it and repaired it, would impose an unreasonable risk.

Connections between a public potable water supply and a nonpotable supply on the premises of a customer, or interior plumbing conditions or practices making back-siphonage of contamination into the public water system a possibility is a controversial point. If a waterborne disease developed as a result of such a condition, would the water works be liable? The point is controversial because some state departments of health seem to feel that the water works should assume the responsibility of making inspections of consumers' premises to discover and correct such dangerous con-

*Reprinted from J.A.W.W.A., Vol. 44, p. 1085 by permission of the Association.

ditions, whereas some water works officials feel that they have no responsibility beyond the service connection. In other words, there is controversy about what a resonable man should do under the circumstances. Inasmuch as the author has, on other occasions, failed to agree with either of these positions, he has been subjected to fire from both sides. It is his opinion today—as it was years ago—that the conduct of a reasonable man would be to use ordinary intelligence, and, when such intelligence told him dangerous conditions existed, force correction or discontinue service. On the other hand, the author does not believe that the water works should allow the public to think that it polices the premises of its consumers, thus making itself liable for damages resulting from conditions of which it had no adequate means of learning.

A water works must, at its peril, furnish water which is safe for domestic use. It is also required by regulatory bodies and the courts to supply a water which is reasonably free of turbidity, color, taste and odor —that is, it must do the best it can in these respects, considering all the circumstances. It is not required to do what is practically impossible, and some variations in quality due to emergencies or drought are not normally considered evidence of poor management. The water works is not expected to deliver to all of its customers water of a particular character needed by some one or more of its customers. Thus, if a manufacturer requires water free from all color or having some other special characteristic not demanded by the customers in general, failure to furnish this special type of water would not be grounds for legal action. Once the manufacturer was led to expect and rely on the water works furnishing such water, however, a reasonable man would notify the manufacturer, if possible, before a change in water quality took place in order to enable him to avoid loss.

Fluoridation

From the standpoint of a lawyer, the problems involved in flouridation are problems which come under the law of negligence. For the purposes of this discussion, it is assumed that the community has taken all appropriate action to indicate a desire for fluoridation and that the equipment and methods to be employed have been approved by the proper health authorities. It is also assumed that the general community recognizes that the addition of fluorides to the public water suply in the indicated amounts will probably result in some significant increase in tooth mottling. It is assumed that in addition to this recognition, there is the belief that the program will result in a substantial reduction in tooth decay, at least among the children, and that there are good prospects that the benefits to the children will carry over into their adult life. It is also assumed that the water works operator and the public know that continued overdosage of the water for a long period would cause a serious and distressing increase of tooth mottling, but that no known adverse side effects are to be anticipated from the program if only proper quantities are added to the water. It is assumed that the public health scientists have established these points to their satisfaction and that their findings have been published and not successfully attacked.

Under these conditions, it is clear that the water works operator is acting as a reasonable man would, and is not exposing his customers to an unreasonable risk when he undertakes to carry out the program as planned. The community has weighed the social advantages of reduction of tooth decay against the risk of some increase in tooth mottling and has chosen fluoridation. Those who suffer tooth mottling as part of the small group so affected would have no right of action against the water works—they had not been subjected to an unreasonable risk. If a very large proportion of the people developed mottled teeth after the program was put into effect, the experts would be justified in the opinion that the water works had been negligent over a long period of time and had put excessive quantities of fluorides into the water. The water works manager knew the danger and knew that the risk of such a result was not outweighed, in the minds of the community, by the reduction in decay; therefore, the water works would be subject to damages. The water works would be found to have acted negligently in permitting the excessive dosage over a long period. The excessive dosage, not the engaging in the approved program, imposed the unreasonable risk on the community. In view of the assumed scientific determination that the experienced results would not come about except after continued overdosage for a long period, the courts would probably say that negligence was the only inference that could reasonably and legitimately be drawn from the circumstances. The doctrine of "res ipsa loquitur" ("the thing speaks for itself") would aply and the time, place, and manner of the negligent acts would not have to be proved.

There would, however, be no liability if an entirely unforeseen adverse side effect developed, because an actor is only responsible for failure to consider circumstances which he knows or should know. The water works operator had no means of knowing that these side effects would develop. Therefore, he was not negligent. To a lawyer the fear of successful suits for damages based on such unforeseen side effects seems groundless.

Public Interest and Property Rights

Two recent cases involving water works should be mentioned because, in deciding them, the courts applied legal principles which water works managers should know. The first case was decided by the Supreme Court of Errors of Connecticut at its June term, 1951, and the second by the Court of Appeals of Kentucky on Mar. 28, 1952, as extended on denial of rehearsing on June 20, 1952.

In the Connecticut case the Greenwich Water Co. held a statutory right to take water from the Mianus River but this statutory right was subject to the riparian rights of owners of property along the river. That is, the water company had no legal right to divert the water of the river —as against those riparian owners—without purchasing or condemning the riparian rights. The majority of those riparian owners purchased, improved, and maintained their properties as country estates, counting on the river as one of the attractive features. Aside from swimming, use of water from the river for lawn and garden sprinkling, watering of chickens, and domestic sanitary needs, the owners valued the water for its enhancement of the beauty of their estates. The water company had not acquired the riparian rights. In 1949, a long period of severe drought began and the normal sources of supply for the company were either cut off or so reduced that emergency conditions for the community developed. By pumping some of the flow of the Mianus River, the company was able to maintain some service. Under these circumstances, a group of influential riparian owners went into court seeking an injunction to restrain the company from diverting any of the waters of the stream. (It is interesting to note that the trial court found as a fact that "a water company in the situation of the defendant should plan for a supply of water to meet conditions as they will be at least ten and preferably fifteen or twenty years in the future.") The trial court refused to restrain the pumping from the river and the riparian owners appealed.

The Supreme Court of Errors in its opinion stated:

> The diversion of the water was without any claim of right, was wilful and, *except for the consideration of the public interest* . . . was inexcusable. . . . It is well within the court's discretion to deny an injunction against the infringement of riparian rights if to grant it would *adversely affect the interest of the public*. . . . Under the circumstances . . . equity demanded that the defendant be allowed a reasonable time within which to make adequate compensation to the plaintiffs for the permanent taking of their water rights if it intends to acquire them, and, if that compensation is not made within such reasonable time, the defendant should be enjoined from further diversion of the waters of the stream. [Author's italics.]

In short, the court held that the temporary emergency invasion of the property rights of the riparian owners should not be restrained where such restraint would adversely affect the interest of the public. Water works managers must never forget the public interest—the public nature—of their work.

The second case is *Daugherty v. City of Lexington*, et al., 249 S.W. 2nd, 755. The opinion of the Court of Appeals of Kentucky, as extended on denial of rehearing, was delivered June 20, 1952. The case involved some very complicated questions on statutory law regarding zoning and even more complicated questions of pleading and practice, but none of these questions is of particular interest to water works managers. The point which is of great interest is the court's attitude toward a property owner's plan to develop his own property in such a way as to endanger a source of public water supply.

Daugherty sought a permit from the board of adjustment of Fayette County for the erection of a restaurant, gasoline station, and tourist cabins on his property, which was 1,100 ft. from the reservoir of the Lexington Water Co. The elevation of Daugherty's property is between 20 and 30 ft. above the water elevation of the lake. Daugherty proposed to care for the wastes from his development with two separate septic tanks, one of 1,000-gal. capacity and the other of 500-gal. capacity, each draining into a separate septic field of drain tile in crushed rock fill. The board of adjustment denied the permit because the proposed methods for water supply and disposal of sanitary waste had not been approved by the county health officer. That officer refused to approve those plans, saying that he thought only in terms of public health and safety and the topography of land in the proposed area. Daugherty contended that his proposed method of sewage disposal is completely adequate, modern, and as satisfactory and safe as it is reasonably possible to obtain; that it will cause no health hazard to the public generally; that the proposed use of his property constitutes a reasonable and natural use; and that to prevent him from so using his property, in order to protect the purity of the water in the reservoir lying below his land, amounts to a taking of his property without just compensation, not for the benefit of the

public generally, but for the benefit of a private corporation. His pleadings did not allege that his disposal system would not endanger the purity of the water in the reservoir.

The point at issue on the aspect of the case in which water works operators are interested may be paraphrased from the court's opinion. Did the health officer and the board of adjustment act arbitrarily and unreasonably and with the sole purpose of protecting the private property of the Lexington Water Company? In answer, the Court of Appeals decided the case against the property owner and, in the opinion, made some very interesting and important points, which follow:

The water company is in substance nothing more than a management corporation, allowed to make a reasonable profit for furnishing water to the city.

The public has a direct interest in the preservation of the purity of the water in the reservoir of the Lexington Water Co. So Daugherty's right to convert his property to a commercial use must be measured against this public interest in determining this question of reasonableness.

He may not use his property in such manner as will endanger the source to which the public must look for its supply of water. [Author's italics.]

This case indicates that a property owner not only has no right to contaminate a public water supply but has no right even to endanger it. The burden is on the property owner to prove that his proposed use will not endanger the purity of the water in a public supply. No longer, under this sound doctrine, will water works be compelled to wait until the purity of supply has been destroyed before taking action. The public interest comes first. The Kentucky decision is in line with, but in a sense a further development of, a doctrine announced in many other jurisdictions.

Other Court Decisions

Two older cases in Pennsylvania may be cited as fairly typical. In *Commonwealth* ex rel. *and Butler Water Co.* v. *Russell* et al, 172 Pa. 506, the Supreme Court of Pennsylvania reversed a decree of the lower ocurt against the commonwealth and the water company and sent the case back for full hearing on the facts. The appellate court opinion suggested certain questions to be considered after the facts had been developed. It said one question was: "whether in other words, the Commonwealth, in the exercise of its police power, may not limit and restrict the individual in the exercise of admitted rights, when the welfare of the public requries it; or whether it is indeed true that the ownership of a few acres of land, or a leasehold interest therein, gives to the holder an unqualified right to destroy the water supply of a city. . . ." The court did not answer these questions directly but its thinking was indicated and was well understood. In *Pennsylvania Railroad* et al. v. *Sagamore Coal Co.* et al., 281 Pa. 233 (Cert. denied 267 U.S. 592) the Pennsylvania Supreme Court, in effect, gave direct answer to the questions suggested in the Butler case. In the opinion it was said, "It has always been under our law a nuisance to pollute a stream from which the public gets its supply of water. . . . There could not be such a thing in the law as a property right to do a wrong. . . . Our conclusion is that defendants have no right of any kind to drain their mine waters into the stream considering the public use which is made of its waters and that their doing so constitutes a nuisance which must be restrained."

There is no such thing as a property right to pollute a public water supply. Even to endanger such a supply may be restrained by the police power of the state and the affected landowner need not be compensated.

Other Problems

Only a very few of the legal problems of water works managers have been touched upon. The legal problems involved in keeping water works enterprises—both publicly and privately owned—financially strong enough to give the type of water service which the communities really need are the most pressing problems which face water works managers. Discussion of these problems would require much space and so must be omitted. The impact of inflation on all water works operations when courts and regulatory bodies tend to give predominant weight to original cost deserves the careful attention of the water works man. If rates are based, in effect on the average net investment in utility plant and property, those rates must be adjusted upward very frequently. Otherwise new customers become a burden, because the increase in net plant and property per added customer goes up each year of inflation and is usually at least double the average investment per customer at any time. Furthermore, consideration might well be given by water works men to the legal problem of determining a fair rate of return. Is a rate fair which is merely equivalent to the rate of return now demanded by new investors who put in the presently devaluated dollars, if it is to be applied to existing investors in common stocks who put in the old-time, "100-cent" dollars? The older investor's ability to buy bread is lessened although he may have the same number of dollars. Wage earners get more dollars now than they did before inflation. Why not give the holder of common stocks of water companies the same hedge against inflation?

WHERE THE WATER DOLLAR GOES

Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill.

It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.

PURCHASING WATERWORKS SUPPLIES AND SERVICES*

Principles and Practices—Equally Applicable in the Sewage Works Field

By HOMER A. HUNTER

Consulting Engineer, Dallas, Texas. Former City Manager for Dallas and Other Cities

WATER works officials responsible for analyzing a set of bids often appear to forget that the law enforces acceptance not of the lowest bid, but of the *lowest and best bid*. The best bid may be the highest in dollars and cents but it may easily be the most adantageous to the city because of other factors involved.

Of course, during the last few years, and particularly during the war, most purchases were probably made wherever the materials could be obtained and too little consideration was given to price and quality. To some extent, availability of equipment and materials is still the deciding factor, but when freedom of choice is possible water works men should exercise considerable caution in buying. Under the law they have a great deal of latitude in the selection of materials, supplies and services to be purchased.

The city manager or council may insist on the purchase of the cheapest article, but, if the water works man knows his business as he should, he will be able to demonstrate that the cheapest buy may not be the best one for the city. He has the responsibility for getting on record a recommendation that is best for the city and he will be derelict in his duty if he takes the easy way out and recommends the lowest price every time. Admittedly it requires some courage to take more difficult position of proving that the more expensive article is best over the years.

Court Decisions

Most city charters require that the *lowest and best bid* be accepted, and the courts have held that it is not necessary to accept the lowest bid but that of the *lowest responsible bidder*. In the case of *O'Brien* v. *Carney* (6 Fed. Supp. 761) the court stated that "responsibility" means more than a pecuniary ability to perform the conditions of the contract; "it includes also judgment, skill, ability, capacity and integrity." In *Interstate Buick* v. *Philadelphia* (164 Pa. 477) it was held that: "'Lowest responsible bidder' means not only pecuniary ability but judgment and skill, and discretion will not be controlled to prevent an award to a higher bidder." In *Clayton* v. *Taylor* (49 Mo. App. 177) the court ruled: "'Lowest responsible bidder' means fitness, responsibility or capacity to perform work, and the determination by council that another was not such will not be reviewed."

Federal Regulations

The United States government now recognizes the difference in quality of various articles and Section 245 of the Navy Procurement Regulations reads, in part:

245.1 *Responsible Bidder.* A responsible bidder is a bidder who: (a) is qualified and eligible, by law and under this regulation; and (b) is financially responsible, and able successfully to fulfill the contract requirements.

245.2 *Other Factors to Be Considered.* Other factors besides price that may be considered in making an award are the following: (a) judgment, skill and integrity of a bidder; (b) reputation and experience of a bidder, and prior work of a similar nature done by him; (c) foreseeable costs or delays to the Government resulting from difference in inspection, shipping, location of supplies, etc.; (d) changes made or requested in any of the general or special provisions; (e) restrictions or conditions imposed in the bid; and (f) disadvantages to the Government that might result from making split awards.

Federal Supply Bureau regulations and army procurement regulations also define "responsible" bidders in similar language.

The low-bid procedure used by many city governments in making purchases has placed too great an emphasis on price and has eliminated high quality manufacturers. Often the low bidder proposes to furnish an article difficult to reject under the specifications but lacking intangible elements of top quality which the more able manufacturer can supply. Specifications and even inspection are not complete and adequate quality controls. Specification of design is relatively easy but specification of quality level is almost impossible. For example, proper design and materials may be used in the manufacture of a fire hydrant and it may come up to the standards set by the specification; yet the workmanship and appearance of the hydrant may be well below the desired standard.

Manufacturers' Service Facilities

In making purchases of water work materials and supplies, consideration should also be given to the facilities provided by the manufacturer for servicing the equipment after it is installed. Because many water work items require constant careful operation, periodic servicing is extremely important. If the manufacturer has adequate service facilities, the city may enjoy a considerable saving by not having to keep parts in stock for repairs.

The federal government is placing more and more emphasis on the manufacturer's service facilities. Recently the Veterans' Administration prepared a specification for the purchase of certain X-ray equipment which would eliminate all manufacturers who did not have established repair and maintenance facilities. As a result of complaints by manufacturers to the comptroller general, that official wrote to the Veterans' Administration:

> It has been held consistently by the accounting officers that the determination of governmental needs and drafting of specifications and advertisements therefor are primarily matters of administrative responsibility, and when the specifications reflect actual minimum needs of the Government for a particular purpose, they are not unduly restrictive of competition merely because one or more manufacturers may not be able to meet their requirements. . . . In connection therewith, it is understood that, in view of the nature of the equipment involved, the proper maintenance of such equipment by the successful bidder is of prime importance. . . . Accordingly, you are advised that, if it be determined that only bidders having established repair and maintenance facilities can meet the specific requirements of the Veterans' Administration for the particular equipment here involved, this office will not be required to object to the insertion of a clause in the invitation for bids excluding all other bidders.

Another item that might likewise be of considerable importance is the location of spare-parts stocks maintained by the manufacturer. It is often necessary to obtain repair parts quickly for certain apparatus and equipment, and stocks of spare parts close by are very comforting.

Hiring Consultants

The purchasing of special services is also of importance in water works operations and should be taken into account. When there is a need for an engineer or other specialist to analyze some particular construction or operating problem encountered, the utmost care should be exercised in the selection of the proper individual for the job. In developing a new water supply or treatment plant or planning additions to the distribution system or the sanitary sewer system, the engineer with the best training and experience should be employed because he will be able to do the most for the least number of dollars spent. The services of a capable engineer can be purchased for about the same amount as those of one less well trained, and there will be no comparison between the character of work done by the two. The operator must live with the works of the engineer, and the better the engineer, the smaller the operating problems will be. Engineers should be selected because of their experience with the particular type of job to be done. The possession of an engineer's license is not sufficient qualification.

Conclusion

Water works men have a great responsibility in purchasing materials, equipment, supplies and services, and they also have the legal right to purchase the best quality available to them. In considering the purchase of such items, it is entirely legitimate for the purchaser to condition the award of the contract on a number of pertinent factors. For materials, supplies, apparatus and equipment, these factors are:

[1] Reliability of operation of similar or identical equipment;
[2] Proven life of the material or equipment;
[3] Probable cost of repair and upkeep;
[4] Speed with which repairs can be made;
[5] Ease of assembly and disassembly;
[6] Availability of repair and maintenance facilities and parts stocks maintained by the manufacturer;
[7] Advantages of standardization of equipment such as meters, valves and fire hydrants; and
[8] Interchangeability of equipment.

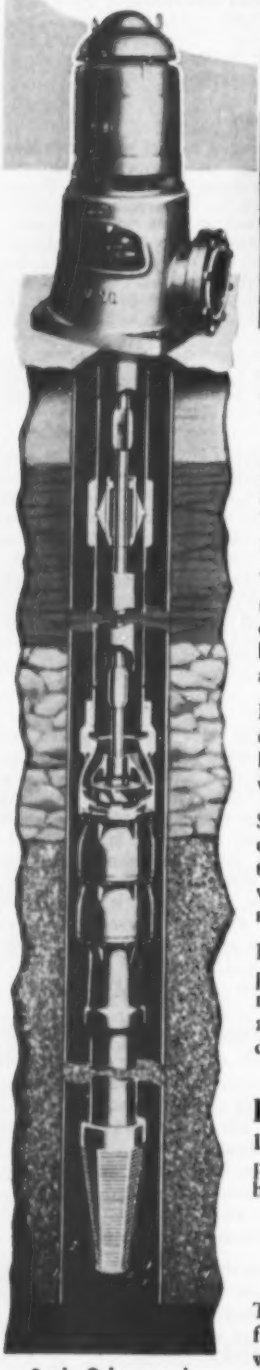
For services, the conditioning factors are:

[1] Experience in doing work similar to that contemplated;
[2] Training of individuals involved;
[3] Responsibility and integrity of individual or company;
[4] Experience in other work closely associated with the particular job to be done; and
[5] Facilities available to the individual or company for doing the work.

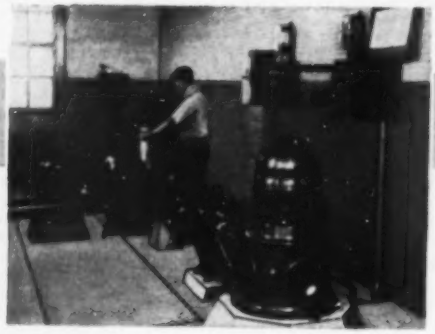
*This paper, presented before the Southwest Section of A.W.W.A., is here published by permission of the Association.

Condensed reference data

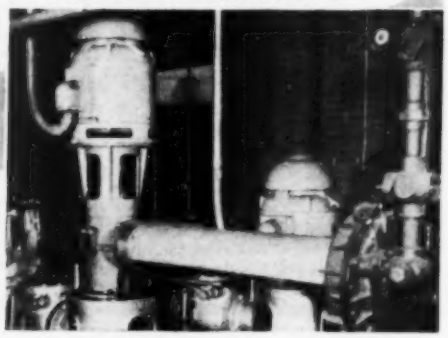
DEMING VERTICAL TURBINE PUMPS



Bowl, Column and Shaft Assembly



Typical Municipal installation of a Deming Turbine Pump with Unit Drive Head (vertical hollow-shaft electric motor).



A dual installation with one pump equipped with Combination Drive direct-connected to steam turbine for emergency use.

ADVANTAGES

Successful performance of Deming Vertical Turbine Pumps in municipal service is due to their following advantages:

WATER LUBRICATION. Requires minimum attention and eliminates any possibility of contaminating water supply with oil lubricants. (Oil lubricated pumps are also available for special conditions.)

LOW OPERATING COSTS. Efficient hydraulic design produces more water with less power. Also, pumps can be run at night when current rates are lower.

SUSTAINED HIGH EFFICIENCY. Semi-enclosed impellers are easily adjustable from the surface to compensate for changes in well conditions or for wear after long periods of service.

LOW MAINTENANCE COSTS. Vital parts of pumps are made from corrosion-resisting metals. Ample size of shaft and related components are engineered for heavy duty service.

PRINCIPAL COMPONENTS

Deming Vertical Turbine Pumps are comprised of three principal component assemblies:

(1) The DRIVE or HEAD assembly.
(2) The COLUMN and SHAFT assembly.
(3) The BOWL ASSEMBLY or PUMPING ELEMENT.

Those three principal components are manufactured in a wide range of standard sizes which may be quickly assembled into almost limitless combinations to meet specific conditions and requirements.

CAPACITIES and APPLICATIONS

Deming Vertical Turbine Pumps are designed for wells 4 to 16 inches or larger in a full range of capacities from 15 to more than 3500 gallons per minute.

In addition to their applications for deep or shallow well service, these pumps are in wide use for pumping from reservoirs, rivers, and other sources.

TYPES OF DRIVE

UNIT DRIVE HEAD for installations where electric power is available. Vertical hollowshaft motors with weatherproof housing are carried in stock for prompt shipment. Totally enclosed and explosion-proof motors are available for special conditions.

COMBINATION MOTOR–RIGHT ANGLE DRIVE for installations where an auxiliary source of power must be available. Engine or other power-unit is direct-connected through flexible shaft to right angle drive. Motor may be removed and operated through drive only.

Send for Bulletin 4700

Construction details and other information about Deming Vertical Turbine Pumps are available in BULLETIN 4700. Write for a copy.

THE DEMING COMPANY • 557 BROADWAY • SALEM, OHIO

BASIC FACTORS IN CENTRIFUGAL PUMP APPLICATION

By ROY CARTER and IGOR J. KARASSIK,
Worthington Corporation, Harrison, N.J.

Part 1—Pump Capacity Units and Elements of Heads

MR. CARTER, manager of the Volute Pump Section, Centrifugal Pump Division of Worthington Corp. received A.B. and M.E. degrees from Columbia University. He entered the employ of Worthington in 1923. He has a broad experience in all phases of pumping problems and on all forms of drives for centrifugal pumps.

MR. KARASSIK, manager of the Multistage Pump Section, Centrifugal Pump Division, received B.S. and M.S. degrees from Carnegie Institute of Technology. With Worthington since 1934, he has specialized in the application of Multistage high pressure pumps and has written numerous articles for technical publications.

IN order to select the most suitable centrifugal pump for a given application, the manufacturer must be given certain information in which data of primary importance is the desired capacity and the head against which the pump will be required to operate while delivering the specified rate of flow.

Units of Capacity

The standard unit of capacity used in the application of centrifugal pumps varies with the field of application, as well as with the standards of the country where it is used. Designers of centrifugal pumps work in U.S. gallons per minute in the United States, imperial gallons per minute in the English territories and cubic meters per hour in countries using the metric system. To illustrate how the units of capacity vary in the various fields of application, the following units of capacity are in regular use in the United States: million gallons per day, cubic feet per second, gallons per hour, barrels per day, barrels per hour, pounds per hour and acre feet per day.

It is a simple matter to convert the various units of capacities to G.P.M. The equivalents for most units of capacities are incorporated in Table I.

In specifying the pump capacity required for an installation, it should be stated in gallons per minute at the pumping temperature and any desired or imposed variation in the range of capacities should be clearly stated. As will be shown later in discussing "Centrifugal Pump Characteristics," centrifugal pumps do not permit as great flexibility in capacity variations, without affecting pump efficiency, as does the reciprocating steam pump or other forms of displacement pumps. As a result, it is generally preferable to have the maximum efficiency of the pump occur at or near the normal capacity conditions.

While any centrifugal pump can run occasionally at a capacity considerably in excess of its rated capacity, this may not always be practical or permissible. The fact that an increase in capacity is accompanied by a decrease in the head generated may prevent operation of the pump at the desired increased rate, especially if the pump operates on a system with a friction component, because the friction losses and therefore the system head will increase with the capacity. Also, emergency over-capacity pumping may be impossible if the prevailing suction conditions leave no margin over those required for the normal rated capacity. Finally if the power consumption increases with the capacity, as it does with the most commonly used types of centrifugal pumps, operation at capacities greater than required may seriously overload the pump motor or other driving element.

Information as to the *minimum* capacity which may be encountered in operation is also of great importance. In certain cases, operation at extremely reduced capacities, even for very short periods, presents a danger and means must be provided in the installation to avoid this. In other instances, the only disadvantage resulting from operation at reduced capacities is poor economy. In many cases economic considerations will dictate the installation of additional smaller units which would be operated during periods of light loads.

Factors Entering Into Heads

Pumping involves the addition of kinetic and potential energy to a liquid for the purpose of moving it from one point to another. This addition of energy to the liquid will cause it to do work, such as, flow through a pipe or rise to a higher level. A centrifugal pump transfers the input of mechanical energy, through a rotating impeller, into kinetic and potential energy to the liquid being pumped. While the centrifugal force developed depends both on the peripheral speed of the impeller and on the density of the fluid being pumped, the amount of energy imparted to the fluid per pound of fluid is independent of the fluid itself. Therefore, for a given machine, operating at a certain speed and handling some definite volume, the mechanical energy applied and transferred to the fluid (in foot-lbs. per lb. of fluid) is the same for any fluid, regardless of density. The pump head, or energy in foot-lbs. per lb. will, therefore, be expressed in feet and, barring viscosity effects, the head in feet, generated by a given pump at a certain speed and capacity, will remain constant for all fluids; thus, in a discussion of heads as applied to centrifugal pumps, it is natural to speak in terms of feet of liquid.

Before discussing the various head terms involved in pumping systems it should be mentioned (1) that heads can be measured in various units, such as feet of liquid, pounds per square inch pressure, inches of mercury and others depending upon the field and the units of measurements of the country; (2) that pressures and head readings can be in

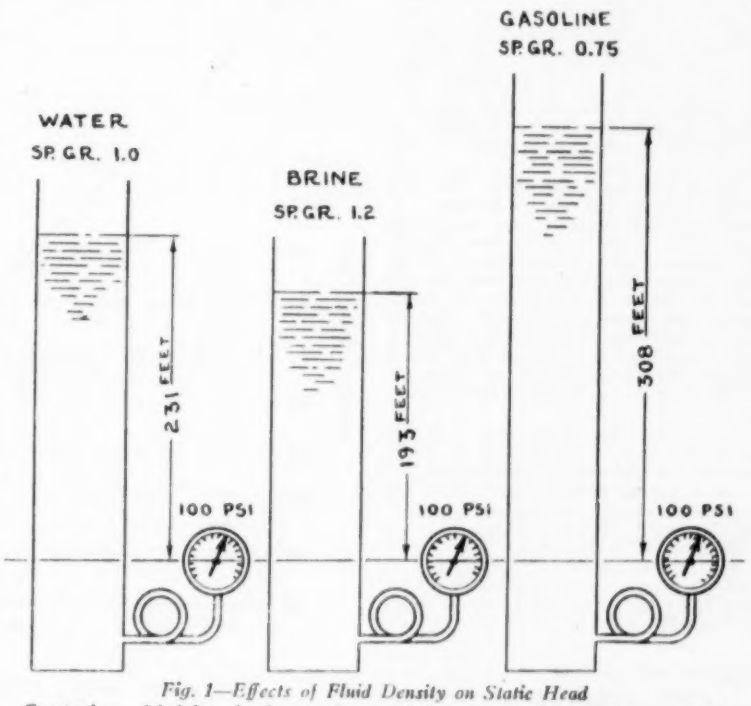


Fig. 1—Effects of Fluid Density on Static Head
Comparison of heights of columns of water, brine and gasoline to effect a 100 psi. pressure at datum line

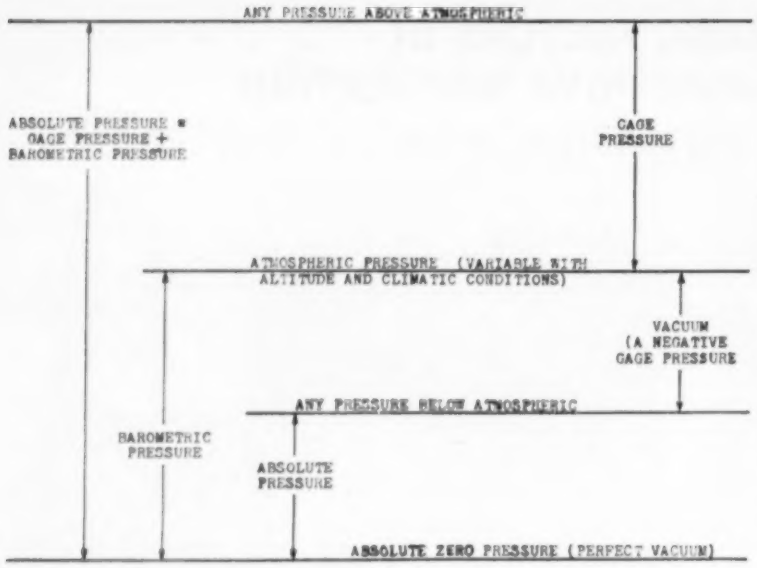

ANY PRESSURE ABOVE ATMOSPHERIC
ABSOLUTE PRESSURE = GAGE PRESSURE + BAROMETRIC PRESSURE
GAGE PRESSURE
ATMOSPHERIC PRESSURE (VARIABLE WITH ALTITUDE AND CLIMATIC CONDITIONS)
VACUUM (A NEGATIVE GAGE PRESSURE
ANY PRESSURE BELOW ATMOSPHERIC
BAROMETRIC PRESSURE
ABSOLUTE PRESSURE
ABSOLUTE ZERO PRESSURE (PERFECT VACUUM)

Fig. 2—Graphical Presentation of Atmospheric, Gage and Absolute Pressures

gage or absolute units; (3) that the difference between gage and absolute units is affected by the existing atmospheric pressure and thus by the altitude; and (4) that, in handling liquids, the pressure at any point in the system can never be reduced below the vapor pressure of the liquid.

Conversion of Pressures to Feet of Liquid

A column of cold water approximately 2.31 feet high will produce a pressure of 1 lb. per sq. in. at its base. Thus when water at ordinary temperatures is involved any pressure in lbs. per sq. in. can be converted into an equivalent pressure in ft. of water by multiplying by 2.31. If the liquid is other than water, its specific gravity in reference to cold water is generally known or can be determined and the column of liquid equivalent to 1 lb. per sq. in. pressure can be calculated by dividing 2.31 by the specific gravity of the liquid.

Figure 1 indicates the effect which the specific gravity has on the height of a column of various liquids for equal pressures. Thus a pump which must handle 1.2 specific gravity brine against 100 psi net pressure would be designed for 193 feet. If the pump has to handle water against the same net pressure it would have to be designed for 231 feet while a pump handling 0.75 specific gravity liquid against the same net 100 psi pressure would have to be designed for 308 feet head.

It is obvious that if the pump designed to handle water was applied on brine service it would develop 231 feet head of brine or 120 psi pressure while if it was applied to pump 0.75 specific gravity gasoline it would develop 231 feet head of gasoline or 75 psi pressure.

The equivalents for the conversion of various pressure and head units, other than feet into feet of liquid, are indicated in Table II.

Gage and Absolute Units

Pressures and their corresponding heads can be expressed either in absolute or gage units, and are generally so specified, like 100 psig. or 160 psi abs. In gage readings the pressure is merely given in relation to the atmospheric pressure while absolute pressures are gage readings plus the existing atmospheric pressure. In other words, the pressure referred to an absolute vacuum, as illustrated in Figure 2.

In most applications it is feasible to work in terms of gage pressure but, occasionally, a complicated problem can be clarified by working entirely in absolute values of pressure.

Effect of Altitude on Pressure

When pumps are installed at elevations above sea level, it must be remembered that there is a decrease in atmospheric pressure of about 1" of mercury per 1000 feet of elevation. At an elevation of 4000 feet, therefore, the atmospheric pressure is 4" of mercury (about 4.5 feet of water) less than at sea level, with the result that a centrifugal pump will operate satisfactorily for the same maximum capacities only if the suction lift is 4.5 feet less than at sea level. For barometric pressures at various altitudes, see Figure 3.

Vapor Pressure

The vapor pressure of a liquid at any given temperature is that pressure at which it will flash into vapor if heat is added to the liquid or, conversely, that pressure at which vapor at the given temperature will condense into liquid if heat is subtracted.

For homogeneous or single component liquids, such as water, the vapor pressure has a very definite value at any given temperature and tables (such as steam tables) are available which give the vapor pressure of such liquids over a wide range of temperatures. Certain mixed liquids, however, such as gasoline, are made up of several components each having its own vapor pressure and partial vaporization may take place at various pressures and temperatures.

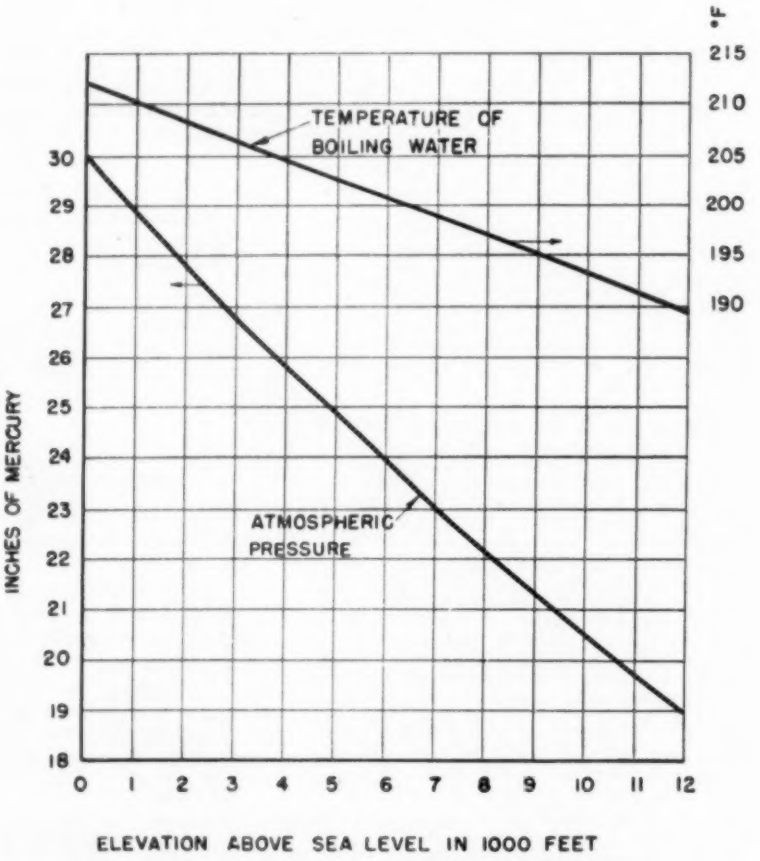


Fig. 3—Atmospheric Pressures for Altitudes up to 12,000 Feet

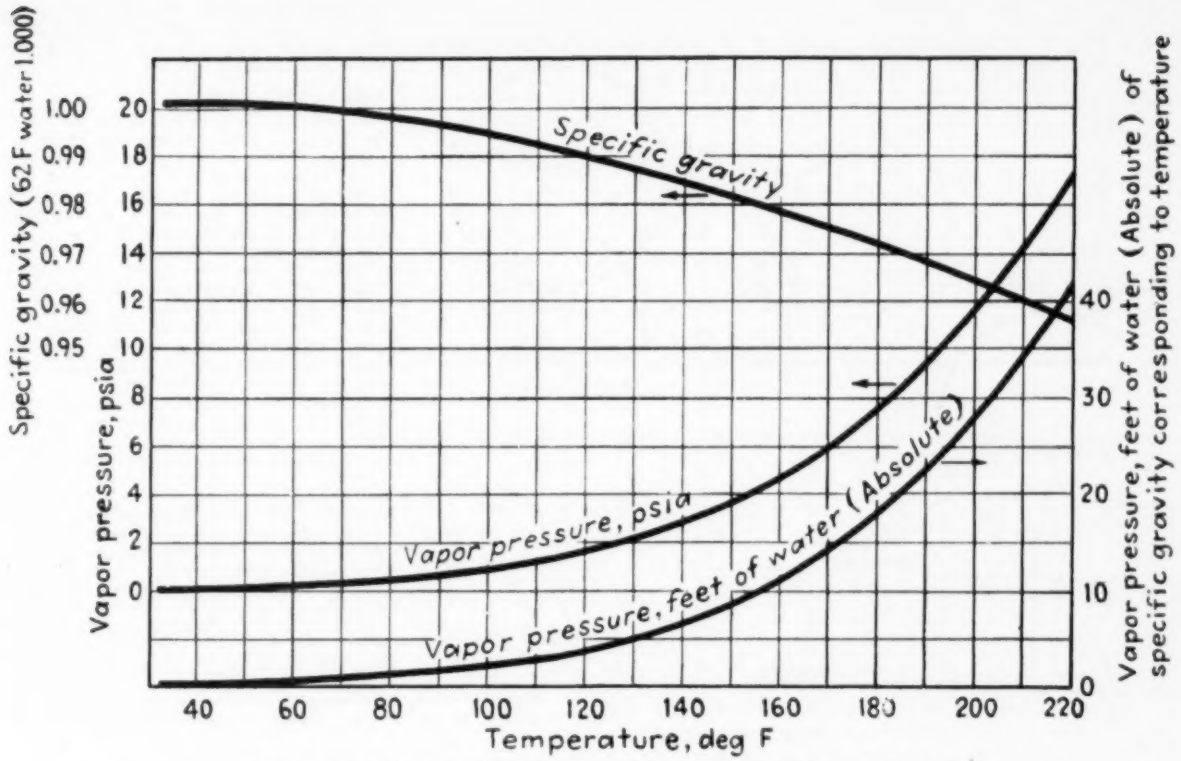


Fig. 4—Specific Gravity, Temperature and Vapor Pressure Relations in Water

Table I
CAPACITY EQUIVALENTS

Various Units		G.P.M.
1 second-foot or cu. ft. per second (c.f.s.)	=	448.8
1 million gallons per day (M.G.D.)	=	694.4
1 imperial gallon per minute	=	1.201
1 million imperial gallons per day	=	834.0
1 barrel (42 gal.) per day (bbl./day)	=	0.0292
1 acre-foot per day	=	226.3
1,000 pounds per hour (#/hr.)	=	2.00*
1 cubic meter per hour (M^3/hr.)	=	4.403
1 liter per second (L/s)	=	15.851
1 metric ton per hour	=	4.403*
1 million liters per day = 1,000 cu. meters/day	=	183.5

* These equivalents are based on a specific gravity of 1 for water at 62° F for English units and a specific gravity of 1 for water at 15° C for metric units. They can be used with little error, for cold water of any temperature between 32° F and 80° F. For specific gravity of water at various temperatures, see Figure 4.

In figuring heads for pumps, it is important that pressures expressed in pounds per square inch, or other pressure units, be converted to feet of liquid at the pumping temperature. This requires care not to use conversion factors applying to other temperatures when making such conversions. For example, the vapor pressure of 212°F. water is 14.7 p.s.i. (standard barometric pressure, at sea level) the equivalent head in feet of water is 33.9 feet of 62°F. water or, since 212°F. water has a specific gravity of 0.959 compared to a gravity of 1.0 for 62°F. water, 33.9/0.959=35.4 feet of 212°F. water. (See figure 4.)

Table II
PRESSURE AND HEAD EQUIVALENTS

1 lb./sq. in.	= $\frac{2.310}{\text{specific gravity*}}$	ft. of liquid	=	2.310 ft. of 62°F water
1" mercury (32°F)	= $\frac{1.134}{\text{specific gravity*}}$	ft. of liquid	=	1.134 ft. of 62°F water
1 atmosphere**	= $\frac{33.95}{\text{specific gravity*}}$	ft. of liquid	=	33.95 ft. of 62°F. water
1 kilogram/sq.cm.	= 1 metric atmosphere			
	= $\frac{32.85}{\text{specific gravity*}}$	ft. of liquid	=	32.85 ft. of 62°F water
	= $\frac{10.01}{\text{specific gravity*}}$	m. of liquid	=	10.01 m. of 15°C water
1 meter			=	3.281 ft.

* See footnote to Table I ** Not commonly used in conjunction with pumps.

Head Terms

In its elementary form, the concept of "head" is the distance that the free surface of a body of water is above some datum line and, as such, represents potential energy or ability to do work. Energy can also exist as a pressure. Some consider that static head is the sum of the pressure head and the static head of elevation; however, generally they are considered separately. In any pumping system the liquid must be moved through pipes or conduits which offer certain resistances or, in other words, have certain frictional losses. This energy dissipation, or head loss, is called a frictional head while that energy which has been converted into velocity energy is called velocity head. Thus, in any pumping system, static heads, pressure heads, friction heads and velocity heads may all be encountered. On the other hand when considering a pump by itself, "head" is a measure of the total energy imparted to the liquid at a certain operating speed and capacity.

System Head

The total head of a system against which a pump must operate is made up of the following components:

1) Static head
2) Difference in pressure existing on the liquid
3) Friction head
4) Velocity head
5) Entrance and exist head losses

Static Head

A static head is a difference in elevation. Thus the total static head of a system is the difference in elevation between the discharge liquid level and the suction

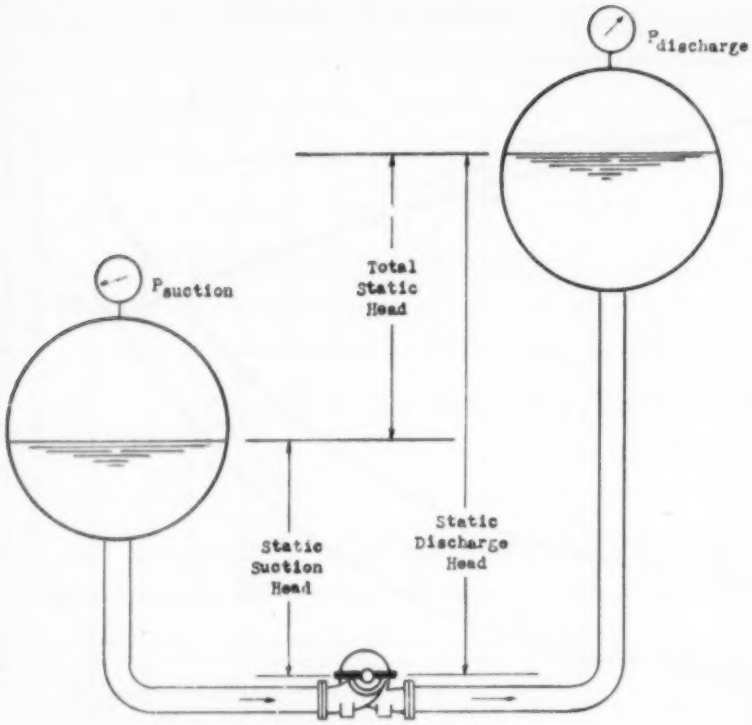


Fig. 5—Illustrating Static Heads
System with pump suction and discharge liquid levels under pressures other than atmospheric

liquid level. (See Figs. 5 & 5a). The "static discharge head" is the difference in elevation between the discharge liquid level and the centerline of the pump. The "static suction head" is the difference in elevation between the suction liquid level and the centerline of the pump. If the static suction head is a negative value because the suction liquid level is below the pump centerline, it is generally spoken of as a "static suction lift."

If either the suction or discharge liquid level is under a pressure other than atmospheric, practice varies as to whether this pressure should be considered as part of the static head or considered separately. The latter generally permits a clearer picture of the system. When the suction supply liquid level is above the pump centerline, the difference in elevation of the suction liquid level and the pump centerline is commonly spoken of as "submergence" rather than "static suction head."

Friction Head

Friction head is the equivalent head, expressed in vertical feet of the liquid pumped, that is necessary to overcome the friction losses caused by the flow of the liquid through the piping, including all the fittings. The friction head varies with the quantity of flow, the size, type and interior condition of the piping and fittings and, finally, with the character of the liquid pumped.

Entrance and Exit Losses

Except for those cases where the suction supply is from a main under pressure, such as a city water supply, the supply of a pump comes from some form of reservoir or intake chamber. The point of connection of the suction pipe to the wall of the intake chamber, or the end of the suction pipe projecting into the intake chamber or reservoir, is called the entrance of the suction pipe. The frictional loss at this point is called the "entrance loss." The magnitude of this loss depends upon the design of the pipe entrance, a well-designed bell mouth resulting in the lowest possible loss.

Likewise on the discharge side of the system where the discharge line terminates at some body of liquid, the end of the piping is called the exit. Generally this exit is of the same size as the piping and the velocity head of the liquid is entirely lost. In some cases the end of the discharge piping is a long taper so that velocity can be effectively reduced and the energy recovered.

Some engineers consider entrance and exit losses as part of the suction and discharge pipe friction losses. Others prefer to consider them separately so as to make sure that they are not overlooked. Considering them separately also has the advantage that it can be easily seen if either or both losses are excessive.

Velocity Head

Velocity head is the kinetic energy in a liquid at any point, expressed in foot-pounds per pound of liquid or, in other words, in feet of the liquid in question. If the liquid is moving at a given velocity, the velocity head is equivalent to the distance the mass of water would have to fall in order to attain this velocity. Thus, "velocity head" can be calculated from the relation:

$$h_v = \frac{V^2}{2g}$$

where h_v is the velocity head in feet
V is the liquid velocity in feet per second
and
g is the acceleration due to gravity or 32.2 ft/sec

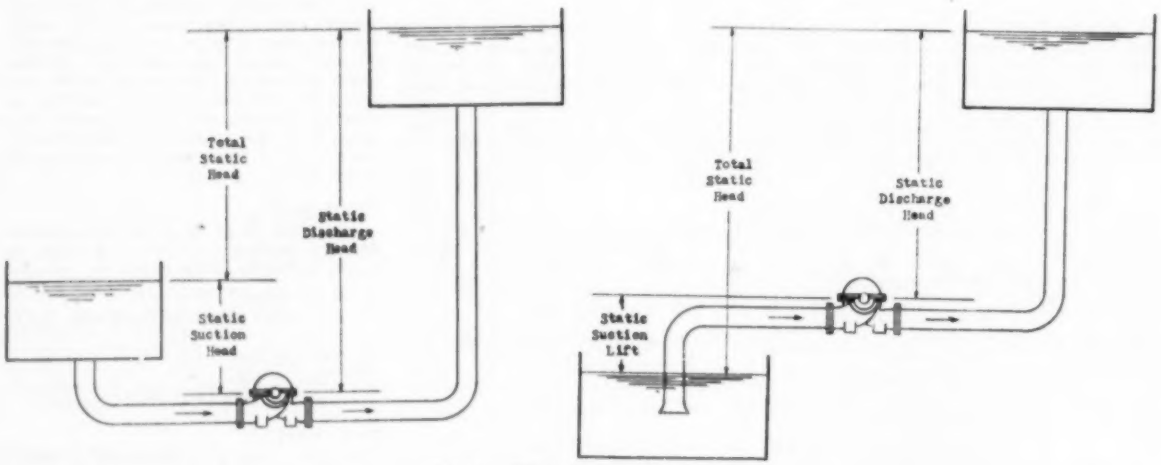
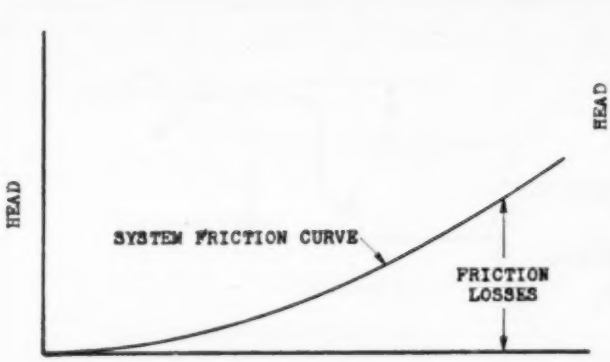
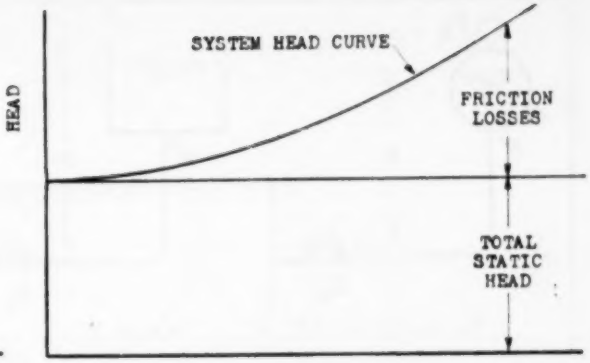


Fig. 5a—Illustrating Static Heads
Discharge liquid levels under atmospheric pressure and suction level above pump centerline (left) and below pump centerline (right).





Figs. 6 and 7—Typical Head vs. Pump Capacity Curves
(Left) Friction Head vs. Capacity. *(Right) System Head vs. Capacity*

In determining the head existing in a pipe at any point, it is necessary to add the velocity head to the pressure gage reading as the pressure gage can indicate only the pressure energy while the actual head is the sum of the kinetic (velocity) and potential (pressure) energies. Thus, to get the actual suction head or discharge head, it is necessary to add the velocity head to the gage reading.

If the suction and discharge pressures of a centrifugal pump are taken at points where the velocities are the same, the velocity head component of each will be the same. Thus, in such a case, the kinetic energy components of both the suction head and the discharge head are equal and the total head can be determined by subtracting the suction gage reading from the discharge gage reading.

In high head pumps the kinetic energy involved is relatively small but in low head pumps it is relatively high. Thus in the case of high head pumps, failure to consider the velocity head in determining a head will not appreciably affect the results. For example, consider a pump handling 1500 GPM with a 6" discharge and 8" suction. The discharge velocity head is 4.5 ft. while the suction velocity is 1.4 ft. If the suction gage showed 8.6 ft. head and the discharge head showed 105.5 ft. head the true total head would be (105.5+4.5) less (8.6+1.4) or 100 ft., while the difference in gage readings is 96.9 ft. Thus the error would be but 3.1% of the total head. Had this been a pump in which the discharge gage reading was 1000 ft., the true total head would be 994.5 ft. while the difference in gage readings is 991.4 ft. The error of 0.3% is too small to be of any concern. If this were a pump in which the discharge head was 45.5 ft., the true total head would be but 40 ft. while the difference in gage readings is 36.9 ft., an error of 7.8%.

Whether or not the velocity head can be ignored depends upon the accuracy of head determination wanted and upon the accuracy of the pressure readings that can be made. In the case of the 1000 feet head reading cited above even with an accurate large scale gage, it would be impossible for anyone to read the pressure within 10 feet, a basic error of 1%.

System Friction Curve

The friction head loss in a system of pipes, valves and fittings varies as a function (roughly as the square) of the capacity flow through the system. For the solution of pumping problems it is often convenient to graphically show the relation between capacity and friction head loss through the system. The resulting curve on such a graph is called the system friction curve as shown in Figure 6. The determinations of friction losses are generally at best rough approximations, as the roughness of the pipe is generally not known. As the friction loss will increase when the pipe tuberculates or otherwise deteriorates with age, it is usual to base the friction loss on constants that have been found from the average of pipe 10 or 15 years old, thus allowing for friction losses in excess of those that will be obtained when the pipe is new. As a result, the pump is generally designed for excess head and delivers over-capacity when installed in a new system or in one which has not suffered from pipe deterioration.

System Head Curve

A combination of the friction head losses, any difference in pressures and the static heads of any system can be shown graphically as indicated in Figure 7. Such a curve, showing the relation between capacity and the resulting head occurring in the system, is called the "system head curve." For systems where the static head or difference in pressures may vary, it is possible to construct curves for the system for minimum and maximum static heads or pressure differentials. Superimposing such system head curves on a pump head-capacity curve permits predicting the capacity that the pump will be able to deliver through the system under the varying conditions that will occur.

Part 2—Pump Head Terms, Definitions and Determination

Part 1 of this article discussed head terms of a general nature. Part 2 will cover head terms used with pumps and, except as otherwise noted, the definitions are based on the current Standards of the Hydraulic Institute.

Suction Head—Suction Lift

As now defined, the total suction head (symbol h_s) is the static head on the pump suction line above the pump centerline minus the friction head losses, including entrance loss in the suction piping for the capacity being considered, plus any pressure (a vacuum being a negative pressure) existing in the suction supply line. Rather than express the suction head as a negative value, the term "suction lift" is generally used when the suction head is negative and when the pump takes its suction from an open tank under atmospheric pressure. As a suction lift is a negative suction head measured below atmosphere pressure, the total suction lift (symbol also h_s) in the static suction lift measured to the pump centerline plus the friction head losses as defined above. (In some cases it is advantageous to express both suction and discharge heads in absolute pressure but generally it is suitable to measure them above or below atmospheric pressure.) A gage on the suction line to a pump, when corrected to the pump centerline, measures the total suction head above atmospheric pressure minus the velocity head at the point of attachment. As a suction lift is a negative suction head, a vacuum gage will indicate the sum of the total suction *lift* and velocity head at the point of attachment.

The three most common suction supply and pump relations are illustrated on Fig. 8.

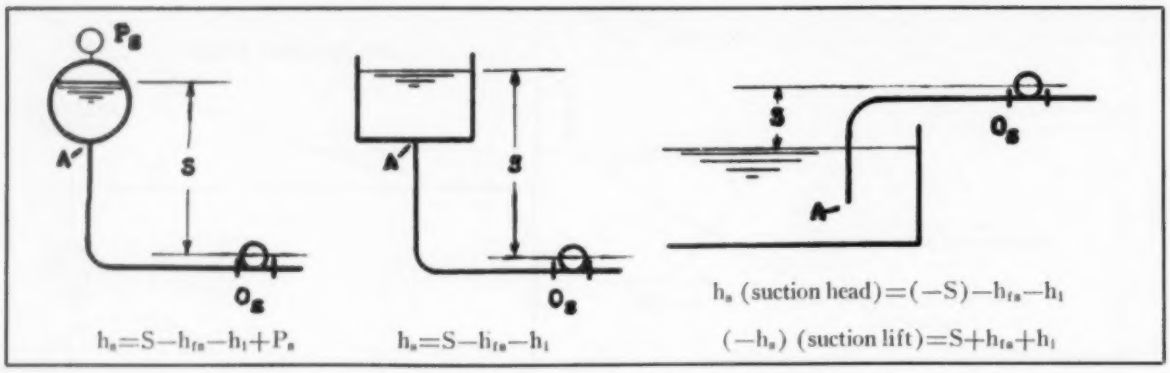


Fig. 8—Suction Head Determination for Three Typical Cases.

CASE I
Suction from source under pressure greater or less than atmospheric and located above pump centerline.

CASE II
Suction from source under atmospheric pressure and located above pump centerline.

CASE III
Suction from source under atmospheric pressure and located below pump centerline.

NOMENCLATURE OF HEADS NOT SHOWN ON DIAGRAMS

h_l = entrance loss at A
h_{fs} = total friction loss from A to O_s
h_{vs} = velocity head at O_s
h_{sg} = gage reading at O_s corrected to pump centerline $= h_s - h_{vs}$

Case I of Fig. 8 involves a supply in a tank under a pressure other than atmospheric and includes all the components of suction head. If h_s is to be expressed as a gage reading and P_s is a partial vacuum, the vacuum expressed in feet of liquid is a negative pressure head and would have a minus (—) sign. If the pressure P_s is expressed in absolute pressure values, h_s will also be in absolute pressure values. Case II is a very common installation with a suction supply under atmospheric pressure located above the pump centerline. Therefore the suction head (expressed as a gage value) has a P_s value of zero which can be dropped from the formula.

Case III is the most common installation for pumps handling water and involves a supply located below the pump centerline. In such a case it is optional whether the suction head be expressed as a negative suction head or in positive values as a suction lift. As the source of supply is below the pump centerline which is the datum line, S is a negative value in our calculations for suction head. It is to be noted that the suction lift formula is the same as for suction head except that both sides have been multiplied by minus one (—1). A gage attached to the pump suction flange corrected to the pump centerline will register a partial vacuum or negative pressure. To get the suction head it is therefore necessary to add *algebraically* the velocity head to this negative pressure or, if it is desired to work in terms of vacuum, the velocity head is subtracted from the vacuum to get the suction lift. For example if the gage attached to the suction of a pump with a 6" suction pumping at a capacity of 1000 GPM of cold water showed a vacuum of 6" of mercury (equal to 6.8 feet of water), the velocity head at the gage attachment would be 2.0 feet of water and the suction head would be (—6.8+2.0) or —4.8 feet of water or the suction lift would be (6.8—2.0) or 4.8 feet of water.

As *most* centrifugal pump troubles occur on the suction side of the pump, it is very important that inquiries for new pumps give the vendors complete information on the suction conditions including any variations that will be encountered in operation. For some complex problems it is often necessary to show the variation in total suction head graphically superimposed on the suction head limitations of the pump being considered in order to see if the pump is suitable.

The Term NPSH

In the pumping of liquids, the pressure at any point in the suction line must not be reduced to the vapor pressure of the liquid. The available energy that can be utilized to get the liquid through the suction piping and suction waterway of the pump into the impeller is thus the total suction head less the vapor pressure of the liquid at the pumping temperature. The available head as measured at the suction opening of the pump has been named "Net Positive Suction Head" and is generally indicated by its initials, NPSH.

Both the suction head and the vapor pressure should be expressed in feet of liquid being handled and must both either be in gage or absolute pressure units. A pump handling 62°F. water (vapor pressure=0.6 ft.) at sea level with 0 feet total suction lift, has an NPSH of 33.9—0.6= 33.3 feet, while one operating with 15 feet total suction lift has an NPSH of 33.9 —0.6—15=18.3 feet.

A pump operating on a suction lift will handle up to a certain maximum capacity of cold water without cavitation occurring. Under these conditions, the NPSH or amount of energy available at the suction nozzle of the pump is the atmospheric pressure minus the sum of the suction lift and the vapor pressure of the water. To handle this same capacity with any other liquid, the same amount of energy must be available at the suction nozzle. Thus, in case of a liquid at its boiling point, (in other words when it is under a pressure equivalent to the vapor pressure corresponding to its temperature), this energy has to exist entirely as a positive head while, if the liquid is below its boiling point, the suction head required is reduced by the difference between the pressure existing in the liquid and the vapor pressure corresponding to the temperature.

It is necessary to differentiate between available NPSH and required NPSH. The former represents a characteristic of the system in which a centrifugal pump works and is the difference between the existing absolute suction head and the vapor pressure at prevailing temperature. The required NPSH is a function of the pump design and represents the minimum required margin between suction head and vapor pressure at a given capacity.

Both the available and required NPSH vary with capacity as illustrated in Fig. 9. With a given static pressure or elevation difference at the suction side of a centrifugal pump, the available NPSH is reduced with increasing capacities due to the friction losses in the suction piping. On the other hand, the required NPSH, being a function of the velocities in the pump suction passages and at the inlet of the impeller, increases basically as the square of the capacity.

A great many factors, such as eye diameter, suction area of the impeller, shape and number of impeller vanes, area between these vanes, shaft and impeller hub diameter, impeller specific speed, the shape of the suction passages and many more enter, in some form or another, into the determination of the required NPSH.

Suction limitations for given capacities in a specific pump were formerly expressed in terms of permissible suction lift at sea level. This required considerable calculation if the pump was to handle water at higher temperatures, if the pump was to handle a liquid other than water, or if the pump was installed at some location above sea level. There is a marked tendency to indicate the capacity vs suction limitation of all centrifugal pumps in a NPSH vs capacity form.

How Suction Conditions Are Specified

The importance of accurately advising the manufacturer of the actual suction conditions for a centrifugal pump at the time of its purchase cannot be overemphasized. A pump will be unable to meet its design capacity conditions unless the suction head can provide enough energy to get the liquid into the pump as discussed above under the subject of NPSH. If a cold non-volatile liquid is to be handled, it is necessary to know whether there is head on the suction or whether the pump will handle a suction lift and if the latter, what will be the maximum lift. In the event that the liquid is hot or under a pressure corresponding

to or near to its vapor pressure, the pump must be installed so as to provide head on the suction and the available submergence must be made known. In case of liquids other than water, information on the pumping temperatures and vapor pressure is also necessary.

Any expected or likely variations in the suction conditions—from maximum to minimum should also be specified.

Discharge Head

The discharge head (symbol h_d) of a centrifugal pump is the head measured at the discharge nozzle and can be expressed in absolute or gage readings.

The discharge head in a system is the algebraic sum of the static head, the friction head losses for the capacity being considered, the exit loss at the end of the discharge line and the terminal head or pressure expressed in feet of liquid.

Established practice is to express the discharge and suction heads of a horizontal pump with the pump centerline as datum and, usually, the discharge and suction head of a vertical pump is given with the centerline of the discharge as datum. The discharge and suction heads can be given with other elevations as datum but, in such cases, it is necessary to indicate at what datum the heads are measured. This practice is often necessary, because, prior to the purchase of a pump, the exact elevations of the pump centerline or discharge centerline have not been determined.

A gage at the pump discharge, when the reading is corrected to the pump centerline, will indicate the discharge head minus the velocity head at the point of attachment.

Typical Discharge Systems

Some typical discharge systems are illustrated in Fig. 10.

Case I shows a system in which the pump delivers to an elevated pressure or vacuum tank in which a pressure other than atmospheric exists, and therefore includes *all* the components of discharge head.

Case II is similar to Case I except that atmospheric pressure exists on the discharge liquid level such as is the case with pumps delivering to open reservoirs and elevated tanks. In this case, and those which follow, if the discharge head is to be expressed as a gage reading, P_s is zero and is therefore not shown in the formulas. Should it be necessary to express the discharge head in absolute values, the atmospheric pressure expressed in feet of liquid is added to the discharge head expressed as a gage reading.

While Case III illustrates an overhead tank, it applies to all cases of "overboard discharge." The actual useful static head (the distance from the pump centerline to the discharge water level) is less than the actual static discharge head D. It is possible, however, to recover part if not all of this by incorporating a siphon leg (see illustrations for Cases IVa, IVb, and V) on the discharge. While Case IVb and Case V would theoretically be the most efficient, it is often desirable for other reasons not to use a sealed discharge. One reason is to prevent the possibility of a back-syphonage when the pump is stopped.

In Case IVa and IVb, a siphon leg is involved and the effectiveness of the siphon will depend both upon the length of the siphon leg and the design of the piping. Varying with the design, the recovery could be anything from 0 to 100%. For example, in Case IVa, if the pipe were very large for the capacity, the pipe would not run full and, as a result, the actual static discharge head would be the distance to the existing (actual) water level in the loop of the piping. All cases involving a siphon leg have to be investigated carefully to see what percentage of head recovery can be expected and the loss included in the friction loss (h_{fd}).

As the absolute pressure at any point in a siphon must be in excess of the vapor pressure of the liquid, it is theoretically possible to have a siphon leg approaching 34 ft. at sea level if the water is cold and air free. In most cases, the water being handled is not air free and a reduction in pressure below atmospheric causes separation of this air thus reduc-

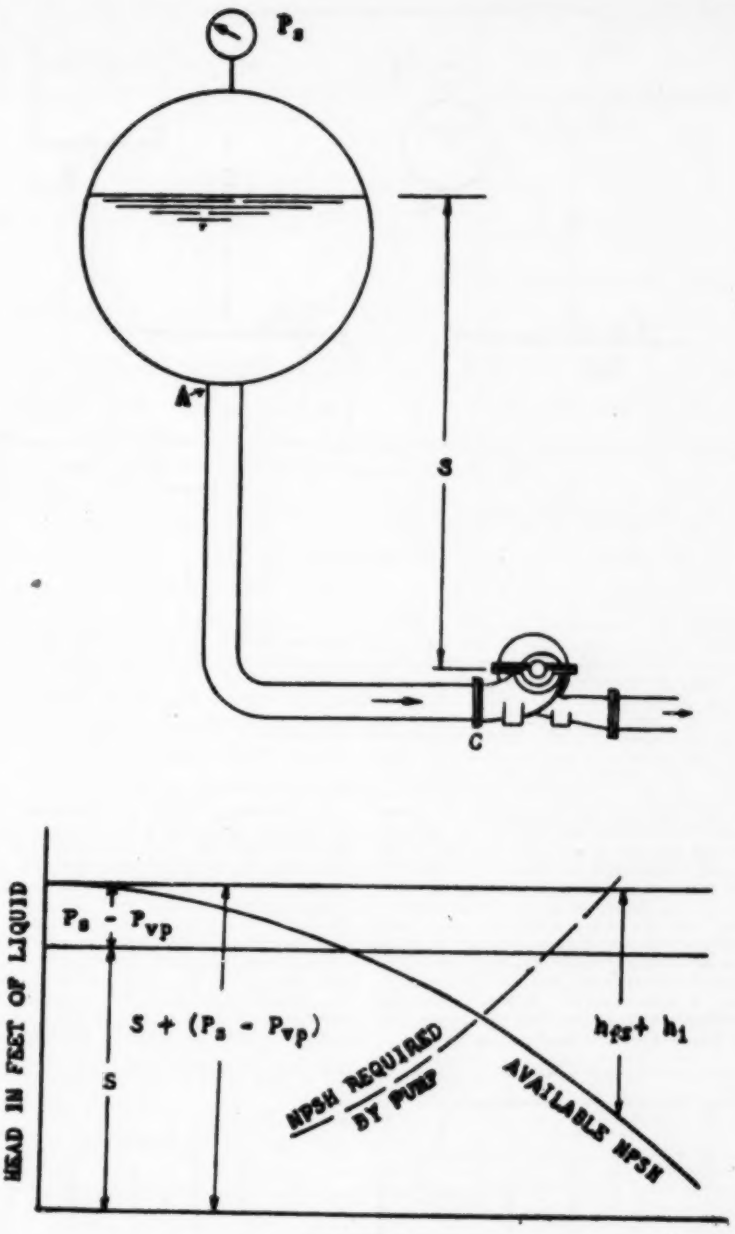


Fig. 9—Determination of "Net Positive Suction Head" (NPSH) Available at Pump Centerline and Relationship of NPSH, Head and Pump Capacity.

$NPSH = S + (P_s - P_{vp}) - (h_{fs} + h_i)$

h_{fs} = friction loss in suction line from A to C

h_i = entrance loss at A

P_{vp} = vapor pressure of liquid at pumping temperature

All heads and pressures must be expressed in feet of liquid at the pumping temperature with proper algebraic signs. While P_s and P_{vp} can either be in gage or absolute values, they must both be measured above the same datum. Some engineers include h_i as part of h_{fs}.

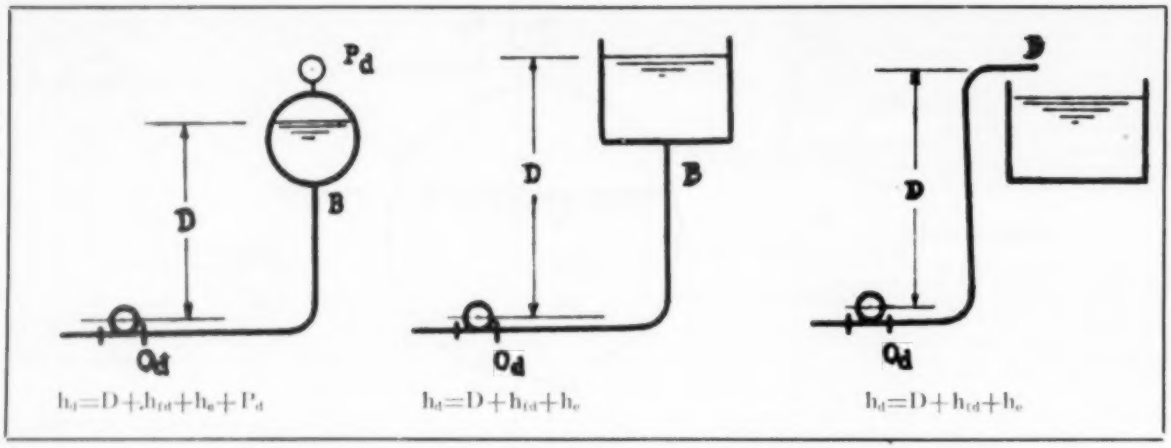


Fig. 10a.—Determination of Discharge Heads for Three Typical Discharge Layouts.

CASE I
Discharge into elevated tank under pressure greater or less than atmospheric.

CASE II
Discharge into bottom of elevated tank under atmospheric pressure.

CASE III
Discharge over edge of elevated tank under atmospheric pressure.

NOMENCLATURE OF HEADS NOT SHOWN ON DIAGRAMS

h_e = exit loss at B
h_{fd} = total friction loss from O_d to B.

ing the effectiveness of the siphon. With water, siphons more than 20 feet high are rarely encountered. It is also questionable if many of those even under 20 feet are 100% effective.

In the use of syphons it is necessary that the design be such that air entrapped will be forced out when operation begins so that the siphon is promptly established. It is also to be noted that, unless the air in the loop can be evacuated, the pump will have to operate during the starting period against a maximum static component indicated as D_1—see Case IVb. In some condenser circulating installations, this results in a much higher starting head than the normal operating head and special consideration has to be given to the characteristic of the pump. This can also be true in Case I if P_d is a negative pressure which is not established until after pumping has commenced, as in the case of a barometric condenser.

In systems where there is a variation in some element of the discharge head, it it generally advantageous to establish the discharge head at various capacities and prepare a graph showing the head variation with capacity. When combined with the suction head, the resulting chart indicates the system head.

Specifying Discharge Head

The discharge head, which determines the design conditions for a pump, should be stated with the understanding that is generally composed of static elevation (or pressure) and frictional losses in the discharge piping and that any variations in the static head must be known in order to determine the maximum and the minimum head against which the pump is to operate. Specifying an excessive total head has actually the same effect as specifying excessive capacity. Since a centrifugal pump will always operate at the intersection of its head-capacity curve and of the system-head curve (discussed in the first installment of this series), a pump which develops an excess of head will, unless artificially throttled, deliver an excess in capacity as its curve will intersect the system-head curve at a greater flow.

By breaking up the discharge head into static and friction head, it is easily seen whether the friction losses are excessive. If the piping to be used is too small, the required pump and its driver (motor or engine) will be more expensive than necessary and the cost of operation greater than if the proper size pipe were used. As a rule of thumb, the friction losses *should not be more than* 10 to 20% of the static head for comparatively short pipe lines.

When the total cost involved is high and justifies an extremely detailed analysis, it is possible to determine the most economic size of pipe by plotting the sum

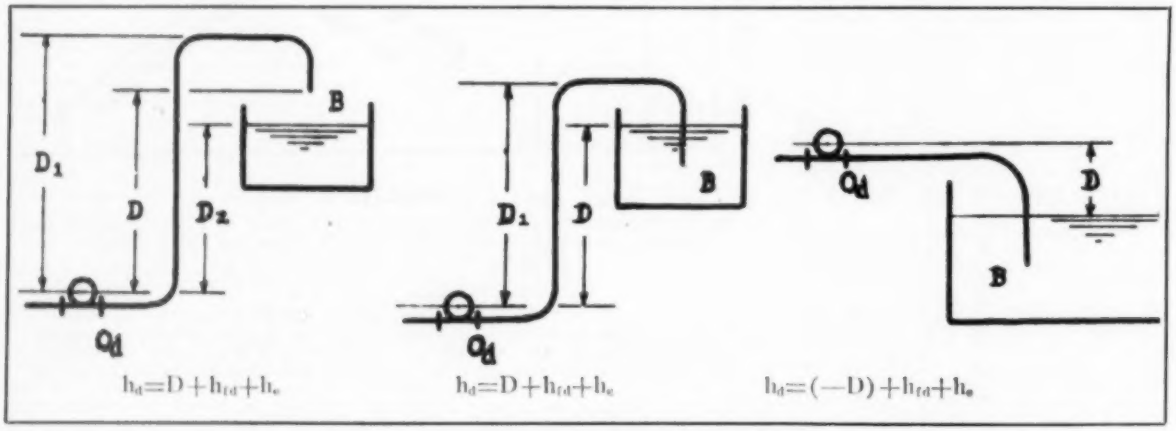


Fig. 10b.—Determination of Discharge Heads for Three More Typical Discharge Layouts

CASE IVa
Discharge through syphon loop into elevated tank. (Discharge not sealed)

CASE IVb
Discharge through syphon loop into elevated tank. (Discharge sealed)

CASE V
Submerged discharge at elevation below pump centerline.

NOMENCLATURE OF HEADS NOT SHOWN IN DIAGRAMS

h_e = exit loss at B.
h_{fd} = total friction loss O_d to B (including syphon losses.)
h_{vd} = velocity head at O_d
h_{dc} = gage reading at O_d corrected to pump centerline $h_d - h_{vd}$.

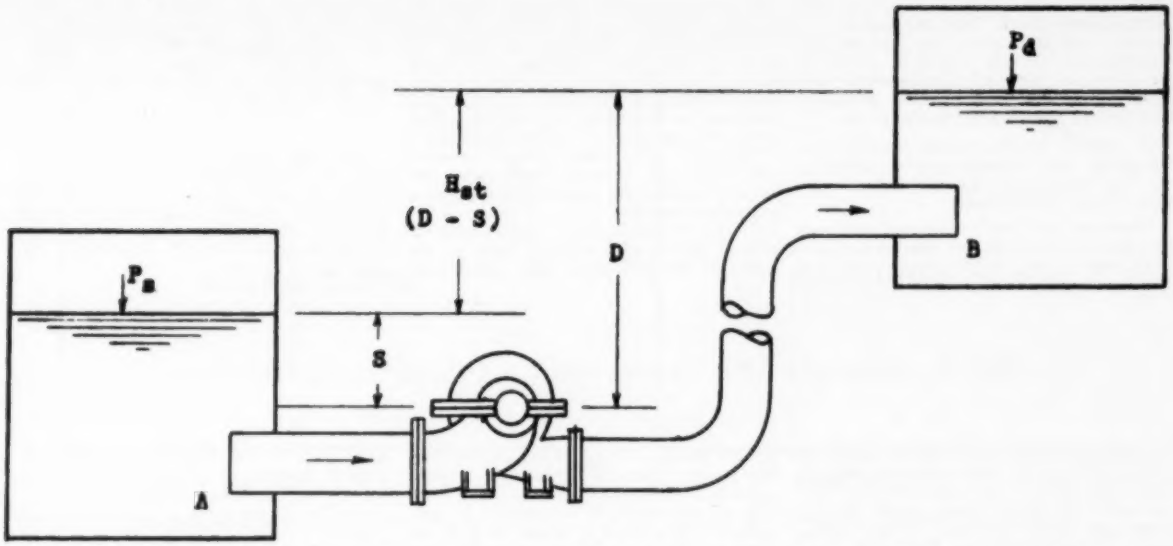


Fig. 11—General Formulas for Suction Head; Discharge Head; Total Head and Available Net Positive Suction Head—NPSH.

	FORMULAS
Suction Head	$h_s = S - h_{fs} - h_i + P_s$
Discharge Head	$h_d = D + h_{fd} + h_e + P_d$
Total Head	$H = h_d - h_s$
	$= H_{st} + h_f + h_i + h_e + (P_d - P_s)$
(Net Positive Suction Head)	$NPSH = S - h_{fs} - h_i + P_s - P_{vp}$

NOMENCLATURE OF HEADS NOT SHOWN ON DIAGRAMS

h_{fs} = friction head loss in suction line
h_{fd} = friction head loss in discharge line
h_f = total friction head loss from A to B
*h_i = entrance loss at A
*h_e = exit loss at B
P_{vp} = vapor press. liquid at pumping temp.

(*Some engineers include these losses in h_{fs} and h_{fd}.)

All heads and pressures must be expressed in feet of liquid with proper algebraic signs. Pressures P_s, P_d and P_{vp} can be either in gage or absolute values but, in any case, must all be measured above the same datum.

To convert pressures in psi (pounds/sq. in.) to feet of liquid, multiply by 2.31 and divide by specific gravity of the liquid at pumping temperature.

of the amortization of initial pump, driver and piping cost and operating cost, versus the initial cost and amortization of various pipe sizes.

In certain special applications, the pump may for short periods be required to develop discharge pressures in excess of the design conditions. A typical example is a condenser water circulating pump which is to be installed in a system utilizing a siphon effect (Case IVb—Fig. 10b). The head to be developed consists only of the frictional losses through the piping and through the condenser itself and is therefore of fairly low magnitude. However, in order to enable the condenser circulating pump to deliver water through the condenser, it is necessary to prime the system (in other words, to discharge water over the siphon) and the design of the pump must be such as to permit it to develop a head at shut-off considerably higher than the normal operating head.

Total Head

The total head (Symbol H) of a centrifugal pump is the energy imparted to the liquid by the pump. It is the difference between the discharge head and the suction head. Thus, as a suction lift is a negative suction head, the total head is the sum of the discharge head and the suction lift. If the discharge head and the suction head are not determined independently, the total head can be calculated by determining the algebraic sum of (1) the static head from supply level to discharge level, (2) all friction losses for the capacity being considered, (3) the entrance and exist losses, and (4) the terminal pressure minus the suction supply pressure. For complex systems involving both vacuums and pressure, it is often easier to convert all the various vacuums and pressures into absolute pressure values expressed in feet of the liquid being handled.

When measured by gages attached to the pump suction and discharge openings the total head is the discharge head (the sum of the discharge gage reading corrected to the pump centerline and the velocity head at the point of attachment of the discharge gage) minus the suction head (the sum of the suction gage reading corrected to the pump centerline and the velocity head at the point of attachment of the suction gage). As it is easy to get the plus and minus signs of the various elements reversed, and as there are numerous precautions to be considered in taking gage readings, it is advantageous in any test to follow the instructions in the Test Code of the Hydraulic Institute.

Figure 11 illustrates the heads involved in the calculations of suction head, discharge head, total head and net positive suction head (NPSH).

Total "Dynamic Head" Outmoded

Total dynamic head, dynamic suction head, dynamic suction lift, and dynamic discharge head are discontinued terminology in regular centrifugal pump field. While total dynamic head referred to the same head as is now called total head, dynamic suction head, dynamic suction lift and dynamic discharge head were defined as the heads measured by gage corrected to the pump centerline and thus did not include the velocity head element.

This led to general misunderstanding if the size of the pump suction and discharge openings were not specified and resulted in different head values for pumps working under identical conditions if their openings were not the same. Furthermore, in determining the total dynamic head from the dynamic discharge head and dynamic suction head it was necessary to correct for any difference in velocity head. The present method of specifying heads is more satisfactory than the "dynamic head" method.

Head Terms for Vertical Wet Pit Pumps

Vertical wet pit pumps may be of the volute type or of the turbine type, the latter covering the propeller type and the vertical turbine pumps, formerly called deepwell pumps. The special problems, both of a hydraulic and mechanical nature, encountered in the vertical turbine pump field has resulted in this type being considered in practically a separate field independent of the regular centrifugal pump field with different practices and terminology.

Both the wet pit pumps of the volute type and those of the propeller type have been handled primarily by engineers in the regular centrifugal pump field. With these two types total head is the discharge head measured at the centerline of the discharge nozzle, with velocity head in-

cluded, plus the static distance to the suction water level. Thus the loss in the suction bell and those of the suction strainer and suction piping, if either is furnished, as well as the losses in the column pipe and elbow in the propeller type pumps are charged to the pump.

In vertical turbine pump practice the following head terminology is used by the National Association of Vertical Turbine Pump Manufacturers.

"Laboratory Head"—discharge pressure by gage measured in feet plus static vertical distance to suction water level in a test setup using the minimum length of column and shafting for a laboratory test.

"Total Head"—discharge pressure by gage in feet plus distance to suction water level. (In case of a closed suction, the total head is discharge pressure plus distance to centerline of suction gage minus suction pressure, all being in feet.)

"Dynamic Laboratory Head"—laboratory head, as defined above, plus the velocity head at the point of the discharge gage attachment.

"Total Dynamic Head"—total head, as defined above, plus velocity head at the point of the discharge gage attachment and, in case of a closed suction, minus the velocity head at the point of the suction gage attachment. (What was formerly called "Field Pumping Head" in the vertical turbine pump terminology is now called "Total Head".)

It is regrettable that there is a difference in terminology between the two fields. In most vases of vertical turbine pumps, the velocity head is a very small portion of the head developed by the pump so its omission actually is of little importance.

Part 3—Characteristic Curves and Centrifugal Pump Relations

Unlike positive displacement pumps a centrifugal pump operating at constant speed can deliver any capacity from zero to some maximum value which derives from the design and size of the pump, and suction conditions. The total head developed by the pump, the power required to drive it, and the resulting efficiency vary with the capacity. The interrelation of capacity, head, power and efficiency is commonly known as the "characteristics of the pump." These interrelations are best shown in graphs which reveal the pump's "characteristic curves." In such graphs it is usual to plot the head, the power input and efficiency against capacity at a constant speed, as shown in Fig. 12. However, it is possible in connection with special problems to plot any three components against any fourth component. When variable speed drivers (motors, etc.) are used, a fifth component, the operating pump speed expressed in rpm. is involved. Where suction conditions may be critical, the limit of suction lift vs. capacity or required "net positive suction head" (NPSH) vs. capacity is often shown. (Note—NPSH was defined and illustrated in Part 2.) In pump design or application studies many other relations may be shown on the same graph.

In Fig. 12 the curve H-Q, showing the relation between capacity and total head, is called the head-capacity curve; and, pumps are often classified on the basis of the shape of their head-capacity curves. This feature will be discussed more in detail later.

The curve η-Q in Fig 12, showing the relation between efficiency and capacity, is properly called the efficiency-capacity curve, but is commonly referred to mere-

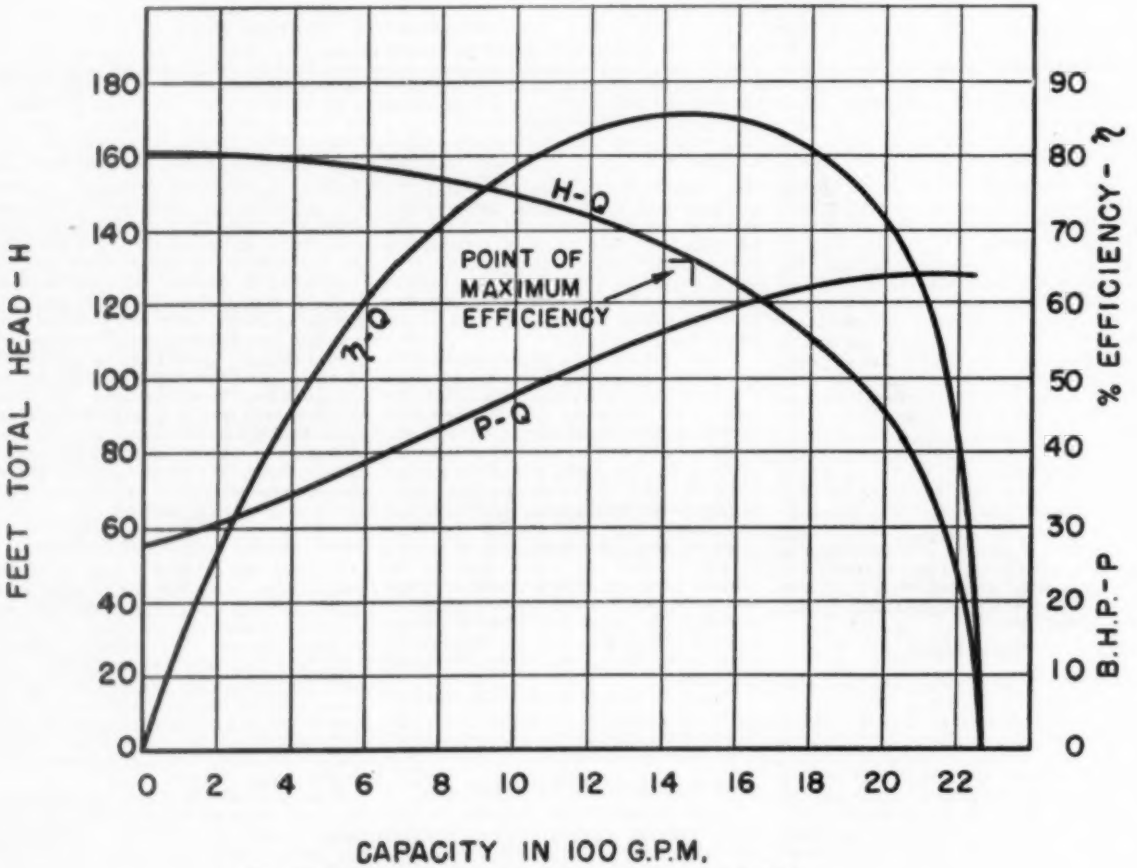


Fig. 12—Specimen Graph of Centrifugal Pump Characteristics
Double suction, single stage volute pump at 1760 RPM with 8" suction and 6" discharge.

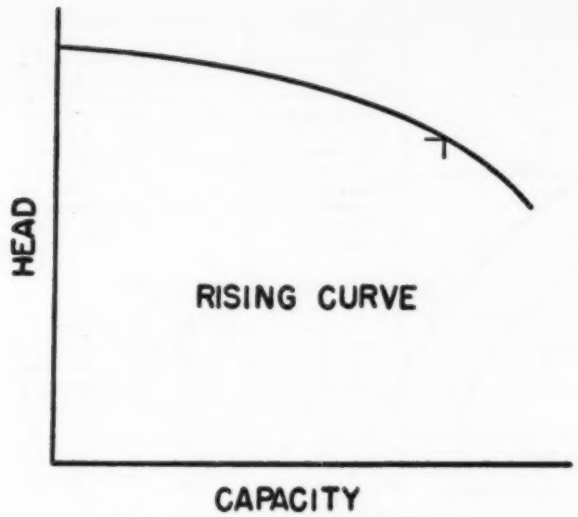


Fig. 13-a—Rising Head—Capacity Curve

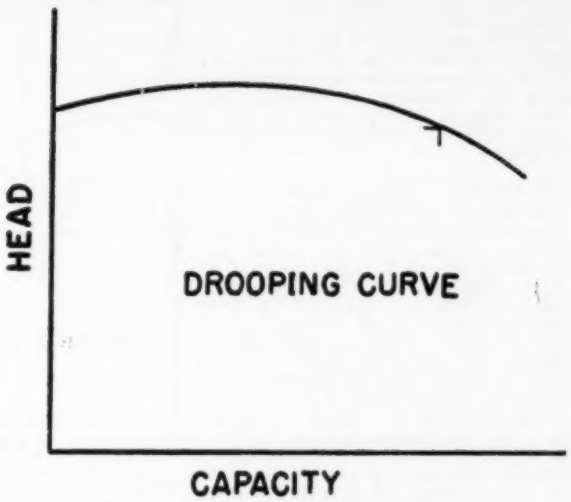


Fig. 13-b—Drooping Head—Capacity Curve

ly as the efficiency curve.

The curve P-Q in Fig. 12, showing the relation between power input and pump capacity is the power-capacity curve, but is generally referred to as the power curve; or as the brake horse-power curve, or the "bhp." curve.

Usually the graph of a pump characteristic is made for a capacity range of zero to the maximum operating capacity of the unit. The scales on the graph for head, efficiency and bhp. all have the same zero line at the base of the graph—see Fig. 12.

In some cases, the curve is made for a limited range in capacity. In other cases, to permit clearer presentation, the head, the efficiency and the power scales are so selected that their zero lines do not coincide. Also, these scales may be enlarged so that their full range cannot be shown on the graph. An example of such plotting of the characteristics of a pump is illustrated by Fig. 18.

Classification of H-Q Curve Shapes

As mentioned above, pump head-capacity curves are often classified by their shapes. Terminology in common use is:

(a) *Rising characteristic* or, more correctly, rising head-capacity characteristic, meaning a curve in which the head rises continuously as the capacity is decreased. (See Fig. 13-a.)

(b) *Drooping characteristic*, a shortened form of the true name of drooping head-capacity characteristic, covering cases in which the head-capacity developed at shut-off is less than that developed at some capacities. (This is also known as a looping curve.) (See Fig. 13b.)

(c) *Steep characteristic*, referring to a rising head-capacity characteristic, in which there is a large increase in head between that developed at design capacity and that developed at shut-off. It is sometimes applied to a limited portion of the curve; for example, a pump may be said to have a steep characteristic between 50% and 100% of the design capacity. (See Fig. 13-c.)

(d) *Flat characteristic*, referring to a head-capacity characteristic in which the head varies slightly with capacity from shut-off to design capacity. The characteristic might be, in addition, either drooping or rising. All drooping curves have a portion in which the head developed is approximately constant for a certain range in capacity. In such cases that range is called the flat portion of the curve. The qualification of flat is also applied at times to indicate the general shape of other curves either for their full range or for a limited range. (See Fig. 13-d.)

(e) *Stable characteristic*, referring to a head-capacity characteristic in which only one capacity can be obtained at any one head. Basically this has to be a rising characteristic. (See Figs. 13-a, -c, -d.)

(f) *Unstable characteristic*, referring to a head-capacity characteristic in which

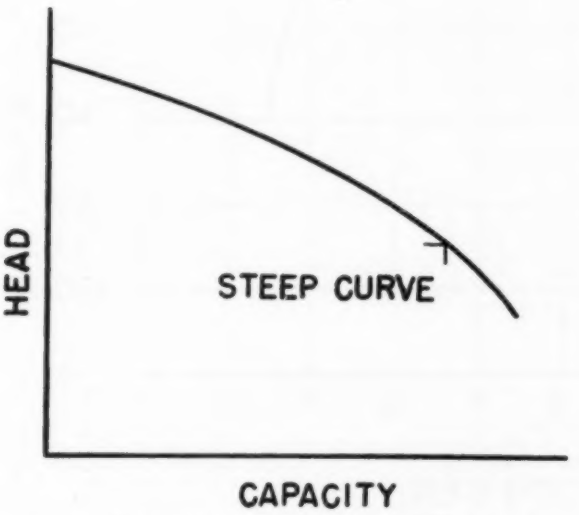


Fig. 13-c—Steep Head—Capacity Curve

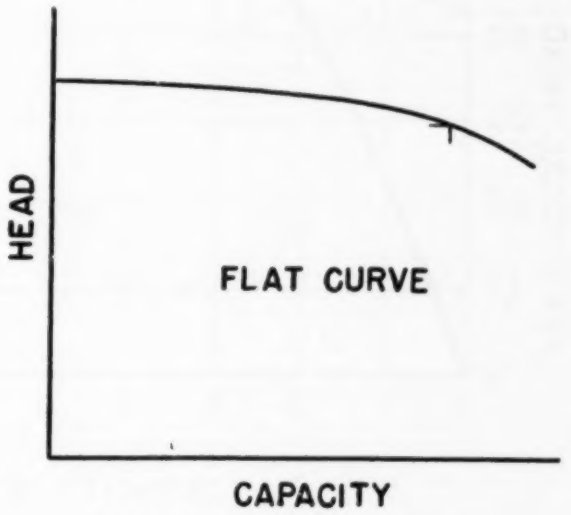


Fig. 13-d—Flat Head—Capacity Curve

the same head is developed at two or more capacities. (See Figs. 13-b, -e). The successful application of any pump is dependent as much upon the characteristic of the system on which it is operated as upon the head-capacity characteristic. Most pumping systems permit the use of pumps with moderately unstable characteristics.

Classification of P-Q Curve Shapes

In addition to the names applied to the shape of the head capacity (H-Q) curves, the power-capacity (P-Q) curves have also been classified according to their shapes. Fig. 14 illustrates a pump characteristic with a power (P-Q) curve (bhp. on graph) which flattens out and then decreases as the capacity increases beyond the maximum efficiency point. This is called a non-overloading curve. When the power (P-Q) curve continues to increase with an increase in capacity, as in the characteristic shown in Fig. 8 as the (bhp.) curve, the pump is said to have an overloading curve. The shape of the power curves (P-Q or bhp.) varies with the specific speed type. As a result the power curve may be one which has a very low value at shut-off, as illustrated in Figs. 14 and 15, or it may be one which has a high shut-off power as illustrated in Fig. 16, or anything between these types. While in Fig. 15 the (P-Q) or (bhp.) curve is of the overloading type with a decrease in head and *increase* in capacity, the (P-Q) or (bhp.) curve shown in Fig. 16 is of the overloading type with an increase in head and *decrease* in capacity.

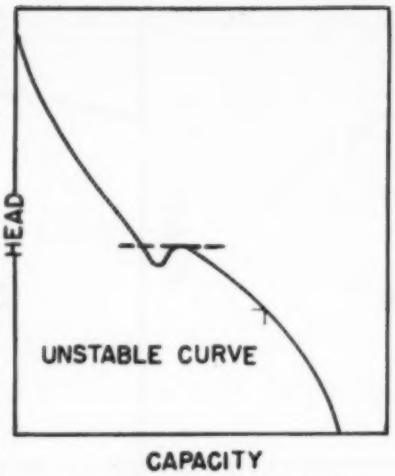


Fig. 13-e—Unstable Head—Capacity Curve

While pumps with non-overloading power curves are advantageous because the driver is not overloaded under any operating conditions, they are not obtainable in all specific speed types of pumps. The actual range in operating conditions to be encountered in the operation of a pump determines the range in power requirements and the driver size should be selected for the power demand to be encountered.

Mathematical Relations of Head, Capacity, Efficiency and BHP

The useful work done by a pump is naturally the weight of liquid pumped in a period of time multiplied by the head developed by the pump. This is generally expressed in terms of horsepower and is called "Water Horsepower." It can be determined by the relation,

$$\text{WHP} = Q \times H \times \frac{\text{specific gravity}}{3960}$$

where

Q = pump capacity in GPM.
H = total head in feet.

The power drive required to drive the pump is regularly determined in horsepower and is called the (bph.) input to

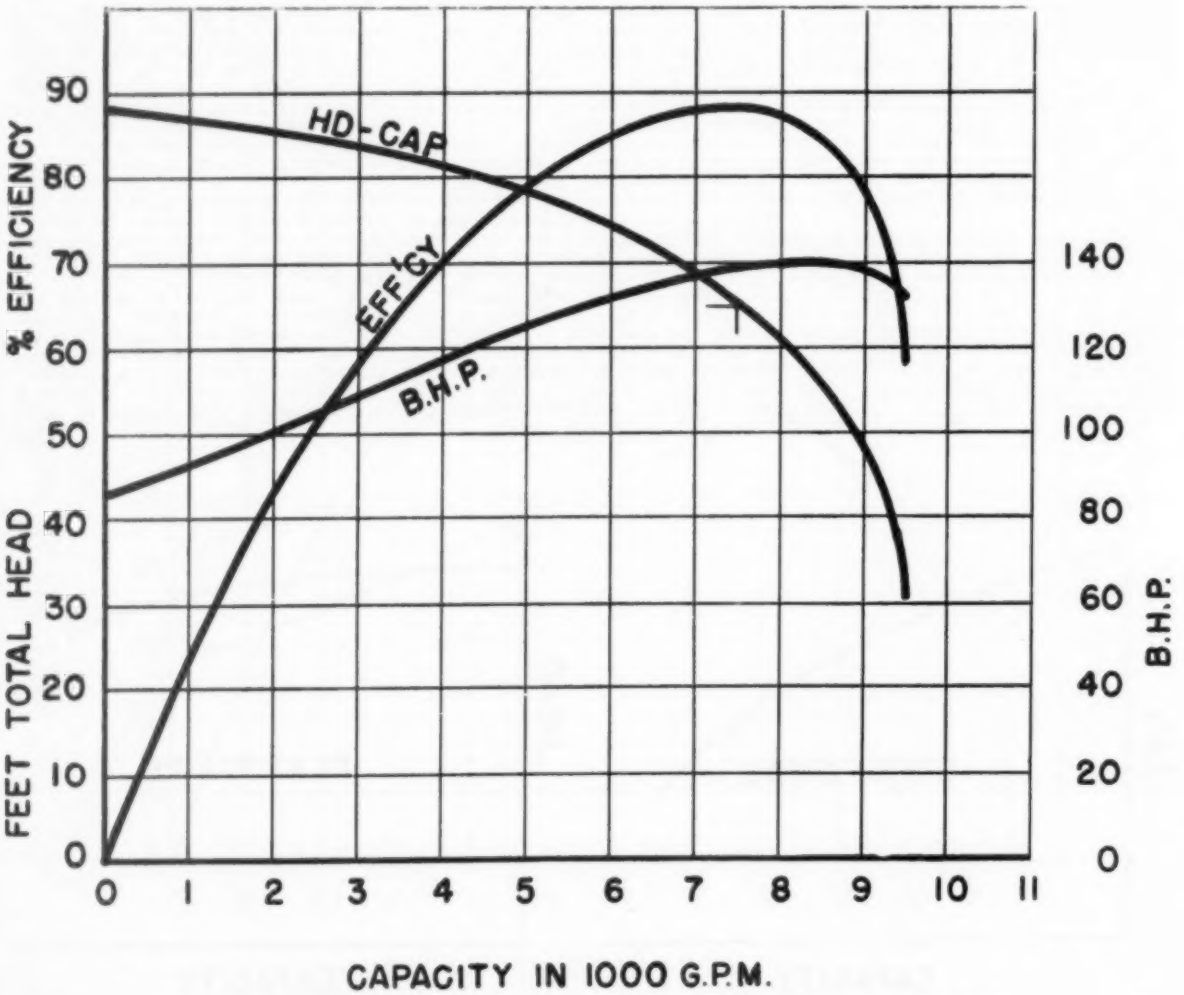


Fig. 14—Characteristics of a Pump With Non-overloading Power Curve With Reduction in Head

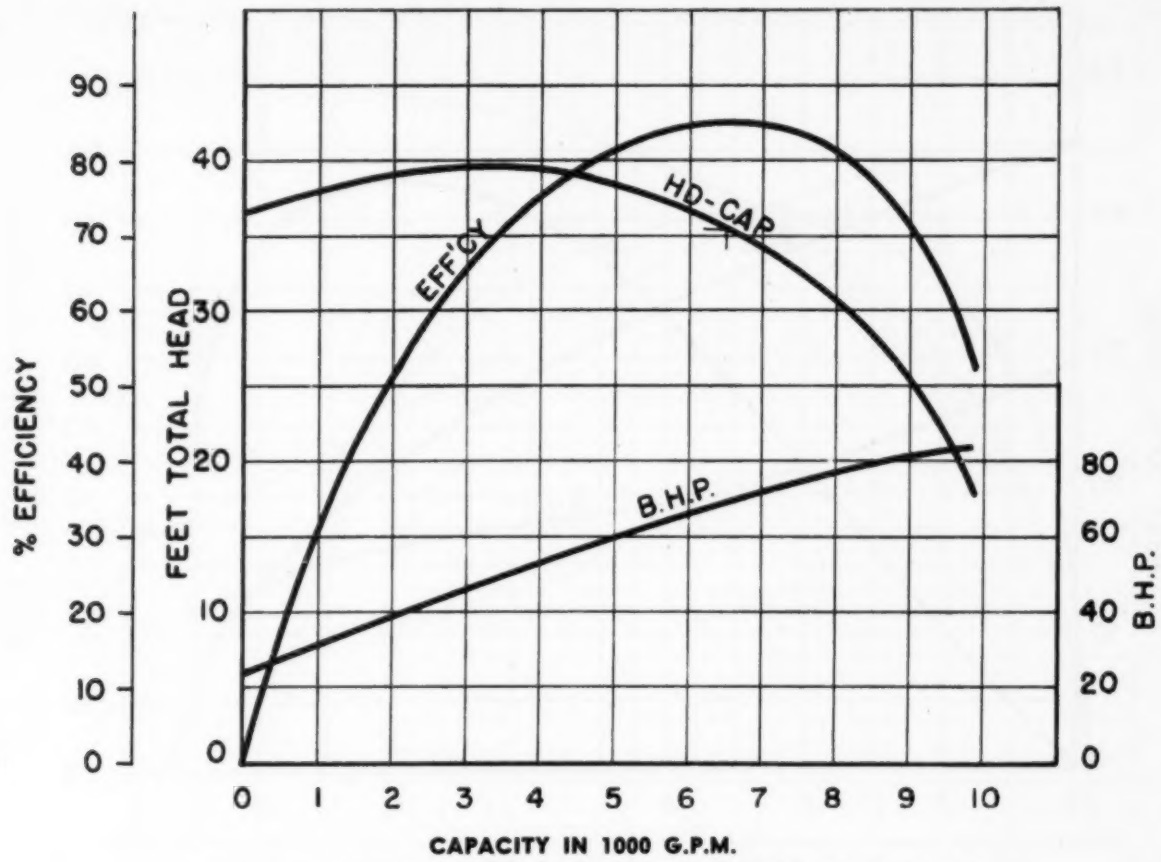


Fig. 15—Characteristics of a Pump With Overloading Power Curve With Reduction in Head

the pump. The ratio of the (whp.) output to the (bhp.) input is the pump efficiency. The relation between (bhp.), capacity, head and efficiency is therefore:

$$BHP = \frac{Q \times H}{\text{efficiency}} \times \frac{\text{specific gravity}}{3960}$$

Type Characteristics

If the operating conditions of a pump at the design speed, namely, the capacity, head, efficiency, and power input at which the efficiency curve reaches its maximum, are taken as the 100% standard of comparison, the head-capacity, power-capacity and efficiency-capacity curves can all be plotted in terms of the percentage of their respective values for the capacity at maximum efficiency. Such a set of curves represents the "type characteristic" or "100% curve" of the pump. Fig. 17 shows the type characteristic of the pump whose performance is shown in Fig. 12.

Centrifugal Pump Relations

There are certain relations whereby the performance of a centrifugal pump can be predicted for another speed than that at which the pump characteristic is known. There are also certain relations whereby we can predict the performance of a pump if the impeller were to be cut down in diameter (within a limit depending upon the impeller design) from the characteristics obtained at the larger diameter.

When the speed is changed:

(1) the capacity for a given point on the pump characteristics varies as the speed, *while at the same time*
(2) the head varies as the square of the speed, and
(3) the brake horsepower varies as the curve of the speed.

Putting these relations in the form of equations, we have

$$Q = Q_1 \times (n/n_1)$$
$$H = H_1 \times (n/n_1)^2$$
$$P = P_1 \times (n/n_1)^3$$

or

$$\frac{n}{n_1} = \frac{Q}{Q_1} = \sqrt{\frac{H}{H_1}} = \sqrt[3]{\frac{P}{P_1}}$$

where—

n = new speed desired in R.P.M.
Q = capacity in G.P.M. at desired speed n
H = head in ft. at desired speed n for capacity Q
P = brake horsepower at desired speed n at H and Q
n_1 = speed in R.P.M. at which the characteristics are known
Q_1 = a capacity at speed n_1
H_1 = head at capacity Q_1 at speed n_1
P_1 = brake horsepower at speed n_1 at H_1 and Q_1

On Fig. 18 there is plotted the 1800 rpm. characteristics of a pump which indicates at that speed it produced 2600 gpm. at 210.2 feet total head, taking 162.5 bhp. and having 84.9% efficiency. If we desire to obtain the 1600 rpm. characteristics, we would correct a number of 1800 rpm. points to 1600 rpm. The 2600 gpm. point mentioned would be corrected to 1600 rpm. as follows:

$H = 2600 \times (1600/1800) = 2311$ GPM
$Q = 210.2 \times (1600/1800)^2 = 166.1$ ft.
$P = 162.5 \times (1600/1800)^3 = 114.1$ BHP

The resulting 1600 rpm. characteristics are also shown in Fig. 18.

These relations for change in speed can be used with safety for moderate changes in speed. They may not be found accurate in case of a large change in speed, particularly in case of an increase in speed.

It is also possible to reduce the diameter of the impeller by actually cutting it down in a lathe. The average impeller can be cut down in diameter about 20% of its original maximum diameter without adverse effect. Cutting it down to less than 80% of its original diameter will generally result in a much lower efficiency. This limit of 20% is of course merely approximate as some designs of impellers can be cut more than this, while others cannot be cut more than a small percentage without adverse effect. Actually, any change in diameter will affect the proportions of the impeller and some variations from the theoretical results should be expected when tested.

It is found if an impeller of a suitable design is cut in diameter that, at the same speed, the characteristic of the pump will have a definite relation to its original characteristics or closely so. These rela-

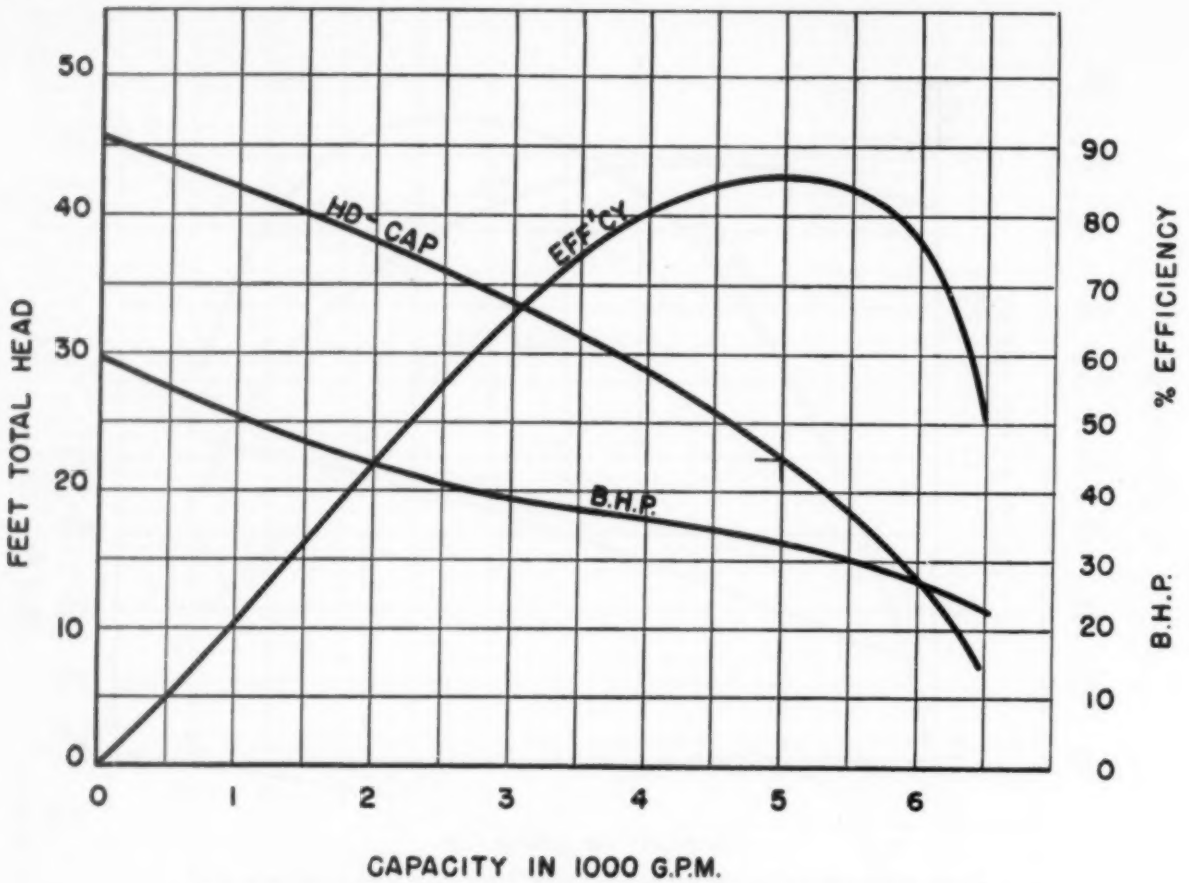


Fig. 16—Characteristics of a Pump With Overloading Power Curve With Increase in Head

tions are:

(1) the capacity for a given point in the pump characteristic varies as the impeller diameter, *while at the same time*—

(2) the head varies as the square of the impeller diameter, and

(3) the horsepower varies as the cube of the impeller diameter.

Expressed in form of equations, these may be listed as:

$$Q = Q_1 \times (D/D_1)$$
$$H = H_1 \times (D/D_1)^2$$
$$P = P_1 \times (D/D_1)^3$$

or

$$\frac{D}{D_1} = \frac{Q}{Q_1} = \sqrt{\frac{H}{H_1}} = \sqrt[3]{\frac{P}{P_1}}$$

where

D_1 = original diameter, (inches)
D = cut down diameter, (inches)
Q_1 = capacity with D_1" impeller
Q = corresponding capacity with D" impeller
H_1 = head with D_1" impeller at capacity Q_1
H = corresponding head with D" impeller at capacity Q
P_1 = BHP with D_1" impeller at capacity Q_1 and Head H_1
P = BHP with D" impeller at capacity Q_1 and Head H_1

Considering again the same pump which at one point at 1800 rpm. gave 2600 gpm., 210.2 ft. thd., 162.5 bhp., 84.9% efficiency and which had an impeller diameter of 14¼" and assuming the impeller was cut to 14" diameter, the corresponding point on the characteristics of the pump with a 14" diameter impeller at 1800 rpm. would be determined as follows:

$Q = 2600 \times (14/14.75) = 2468$ GPM
$H = 210.2 \times (14/14.75)^2 = 189.4$ ft.
$P = 162.5 \times (14/14.75)^3 = 139.$ BHP

Doing this likewise with a number of other points, sufficient points on the 1800 rpm. characteristics of the 14" diameter impeller could be obtained to permit drawing the curves making up Fig. 19.

The most common problems utilizing these relations are to determine the change in speed, the change in diameter of the impeller, or a combination of both necessary to produce a head-capacity characteristic passing through a given point. For example, suppose we have to meet the condition of 3000 gpm., 180 ft. thd. Since this falls below the head-capacity (H-Q) curve of the 14¼" impeller at 1800 rpm. shown on Fig. 18 we can obtain the desired (H-Q) by reducing the speed or reducing the diameter of the impeller.

If the desired pump which is to give 3000 gpm. 180 ft. was speeded up or the impeller diameter increased so that point on the characteristic became 3100 gpm., the head, at the same time, would have become 180 x $(3100/3000)^2$ or 192.2 ft. Similarly, if 3200 gpm. was obtained by a further increase in speed or impeller diameter the head would be 180 x $(3200/3000)^2$ or 204.8 feet. Plotted as shown in Fig. 18, these form a section of a curve (A). This intersects the 1800 rpm. (14¼" D_2) H-Q characteristic at 3135 gpm. 196.5 feet indicating the point on that characteristic from which we have to work. Now if we are to obtain 3000 gpm. at 180 ft. thd., we can determine the required speed by calculation of 1800 x (3000/3135) or by 1800 x $(180/196.5)^{1/2}$ both of which give 1723 rpm. Should it have been that no speed change was desired, it would have required a diameter change of 14.75 x (3000/3135) or 14.12". Had the new driver run at 1760 rpm. the 14¼" diameter impeller would have given 3065 gpm. 187.9 feet thd. requiring in addition a cut in the impeller diameter to 14.44". In all three cases a new curve which would pass through 3000 gpm.: (180 ft. thd. can be plotted by stepping down a number of the 1800 rpm. 14¼" diameter curve points, the capacities being reduced by the ratio of (3000/3135) with the corresponding heads being reduced by the ratio of $(3000/3135)^2$ and the corresponding bhp.'s being reduced by the ration of $(3000/3135)^3$ or the bhp.'s can be calculated from the resulting capacity and head and the pump efficiency at the point in question.

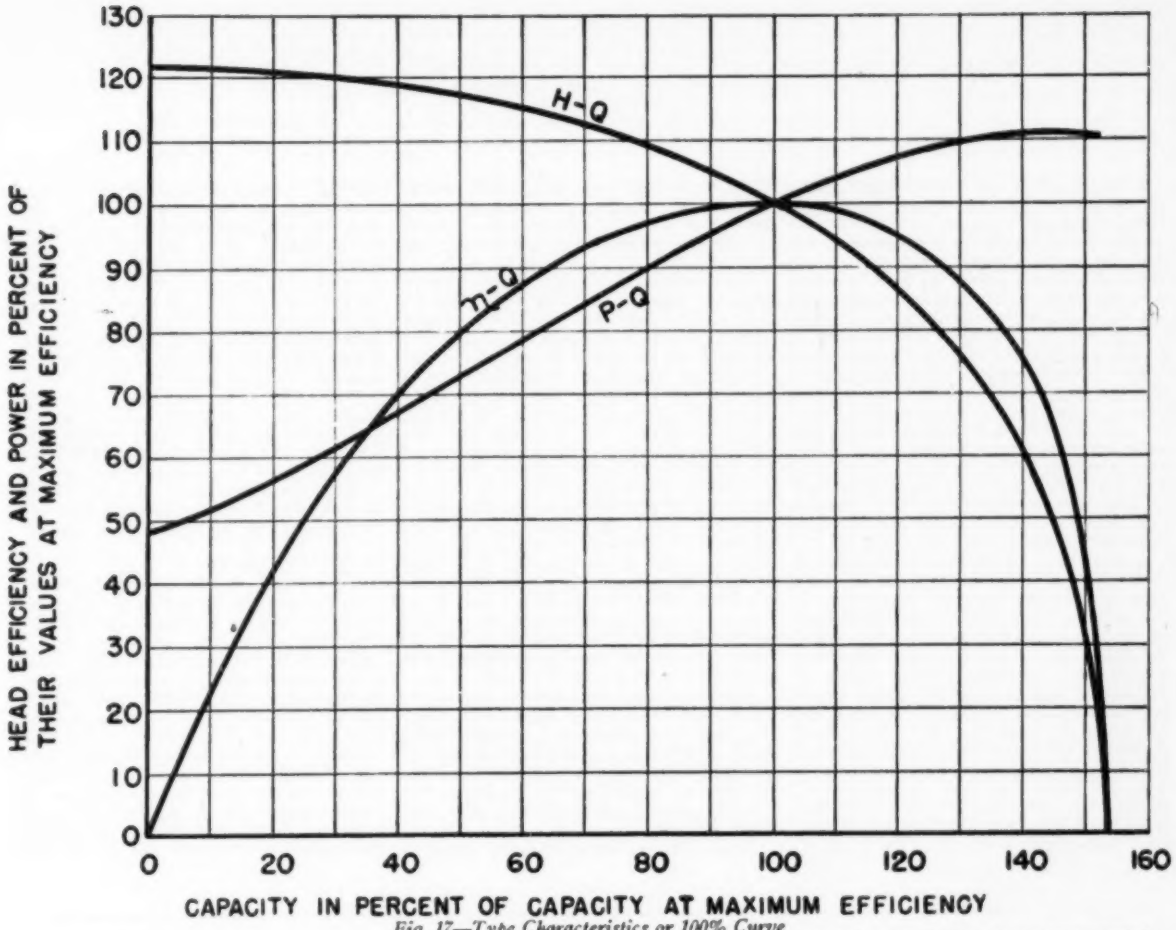


Fig. 17—Type Characteristics or 100% Curve

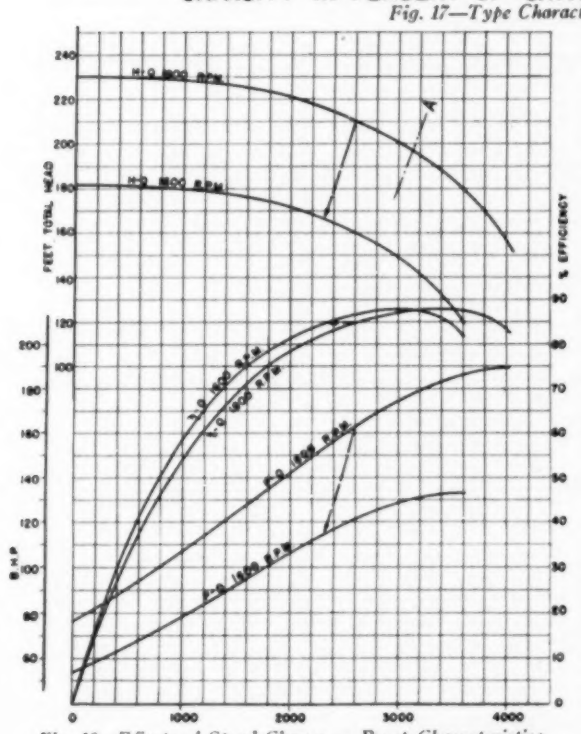


Fig. 18—Effects of Speed Charge on Pump Characteristics

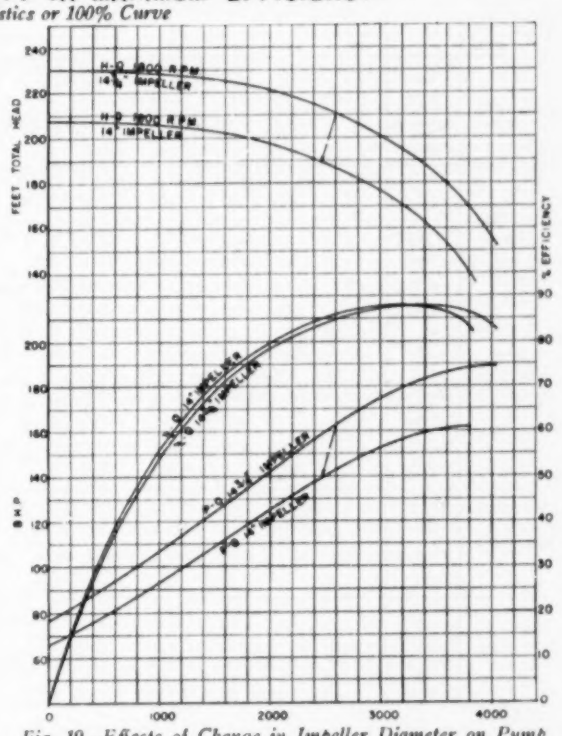


Fig. 19—Effects of Change in Impeller Diameter on Pump Characteristics

Part 4—Rating Curves and Charts; Model Pumps; Specific Speed

A rating curve for a centrifugal pump of specific design shows in a condensed form, the possible range of applications of that pump, either for a range in speed or for a range in impeller diameter. Some small centrifugal pumps for belt drive are manufactured in lots for stock sale, and the most efficient operating speed for each installation is obtained by selecting a proper pulley ratio to give the head and capacity condition desired. A curve showing the head, capacity, and B.H.P. for such a pump at a number of speeds, could be utilized for determining the speed necessary and the power involved. These rating curves are now rarely used. Instead, a table such as is partially shown in Fig. 20 is generally more convenient and permits showing a number of pump sizes on the same sheet.

A few lines of pumps, notably small motor driven stock units, are made with several different impeller diameters, of the same or different patterns, which load up various sizes of motors. A rating curve for this type is shown in Fig. 21. With such a line of pumps, a pump with a 25 HP motor and an impeller which would approximate the results shown on curve (2) would be furnished if the desired head condition fell anywhere within the zone between the H-Q curves (2) and (3) in Fig. 21. Thus, for some customer's requirements, such as 250 GPM 200 feet total head, the pump supplied would produce more capacity or head than required. When installed, this unit would either give excess capacity or excess pressure, depending upon the system, unless wasteful throttling were employed to increase the frictional head artificially.

For pumps which are built-to-order with an impeller pattern and diameter individually selected for the prevalent service condition, a curve showing, for a given speed, the range in conditions that can be met by a given impeller design or by several impeller designs, is used. These are generally complicated in appearance because the efficiency that can be obtained varies with the diameter of the impeller. This variation in efficiency is covered either by iso-efficiency curves, as shown in Fig. 23, or by figures on the curves of similar points ($Q/Q_1 = \sqrt{H/H_1}$ relation) or lines approximating that relation as shown in Fig. 22. For their proper use, rating curves must also show the limits of suction lift at sea level (Fig. 23) or the required minimum net positive suction head (NPSH) shown in Fig. 22. Note that NPSH has been defined and illustrated in Part 2 of this series.

Naturally, with such charts, one is required for each motor speed for which the particular pump may be advantageously offered. For unusual conditions of driver speeds not covered by a curve, the use of a standard relations for speed changes permit determining what the pump will do.

It should be noted that the required NPSH vs capacity relation for a given impeller design, at a given speed, varies with the diameter to which the impeller is machined. With low specific speed types, the variation over the usable range of impeller diameter is small and a single curve as on Fig. 22 can be used to apply to all diameters even though it is slightly conservative for the maximum impeller diameters. When the required NPSH vs capacity for an impeller design varies considerably over the range of useful application of impeller cutdowns this single curve to show required NPSH is not practical and the required NPSH can best be shown by diagonal lines like the suction lift limit lines on Fig. 23, but labeled with NPSH values or with both suction lift and required NPSH values.

Suction Lift Limitations

If the suction lift limitation (at sea level and with 62° F water) for any head-capacity point of a pump is known, it is a simple matter to determine the required NPSH at that point as the NPSH is the atmospheric pressure minus vapor pressure minus suction lift. As the atmospheric pressure at sea level is 14.7 psia or 33.9 feet of 62°F water and the vapor pressure of 62°F water is 0.26 psia or 0.6 feet of 62°F water, standard atmospheric pressure minus the vapor pressure is 33.3 feet of water. Thus 33.3 feet minus the indicated suction lift limit gives the required NPSH. Similarly, 33.3 feet minus

GPM		TOTAL HEAD IN FEET															
		20	25	30	35	40	45	50	55	60	70	80	90	100	110	120	130
200	Size-Type	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1			
	HP	1.6	2.0	2.4	2.8	3.25	3.75	4.2	4.65	5.05	6.1	6.85	7.9	9.0			
	RPM	1010	1090	1170	1240	1310	1380	1440	1500	1550	1660	1750	1845	1930			
	Size-Type		3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1
	HP		2.25	2.6	3.0	3.3	3.6	4.1	4.6	5.0	6.2	7.3	8.3	9.4	10.5	11.9	13.1
	RPM		830	890	945	1000	1048	1095	1140	1185	1275	1355	1430	1500	1568	1635	1700
225	Size-Type	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1			
	HP	1.9	2.3	2.7	3.2	3.65	4.15	4.7	5.1	5.55	6.5	7.6	8.6	9.7			
	RPM	1055	1130	1205	1280	1345	1410	1470	1530	1585	1685	1785	1875	1960			
	Size-Type		3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1
	HP		2.6	2.9	3.3	3.6	4.0	4.6	5.0	5.5	6.6	7.8	8.9	9.8	11.1	12.5	13.8
	RPM		850	907	962	1015	1065	1113	1155	1205	1290	1370	1445	1510	1580	1647	1710
250	Size-Type	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1			
	HP	2.2	2.6	3.1	3.6	4.1	4.6	5.1	5.6	6.2	7.1	8.2	9.2	10.5			
	RPM	1095	1170	1245	1315	1385	1450	1510	1565	1620	1720	1815	1900	1990			
	Size-Type		3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1
	HP		2.9	3.2	3.6	4.0	4.4	4.9	5.5	5.9	7.2	8.3	9.5	10.4	11.7	13.2	14.6
	RPM		870	927	980	1035	1085	1130	1175	1220	1305	1385	1460	1525	1593	1660	1720
300	Size-Type	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1	2½-CF-1				
	HP	3.0	3.5	4.05	4.55	5.1	5.65	6.25	6.75	7.3	8.5	9.65	10.9				
	RPM	1190	1265	1335	1400	1465	1530	1590	1645	1700	1800	1885	1970				
	Size-Type		3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1
	HP		3.5	3.8	4.3	4.8	5.3	5.8	6.5	7.0	8.2	9.6	10.8	12.2	13.1	14.9	16.4
	RPM		920	972	1025	1075	1125	1173	1220	1260	1340	1420	1490	1555	1620	1690	1750
350	Size-Type		3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	
	HP		4.1	4.6	5.1	5.5	6.3	6.8	7.6	8.2	9.4	10.8	12.2	13.5	15.0	16.5	
	RPM		970	1025	1075	1120	1175	1220	1265	1305	1380	1455	1525	1595	1660	1720	
	Size-Type			4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1
	HP			4.2	4.8	5.6	6.2	7.0	7.7	8.4	10.3	11.8	13.6	15.3	17.6	20.1	21.8
	RPM			905	965	1020	1070	1125	1170	1215	1305	1387	1467	1537	1610	1677	1745
400	Size-Type		3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1	3-CF-1		
	HP		4.9	5.4	6.0	6.5	7.2	8.0	8.6	9.4	10.7	12.4	13.9	15.2	16.9		
	RPM		1025	1080	1130	1170	1225	1270	1310	1350	1425	1500	1567	1635	1700		
	Size-Type			4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	4-CF-1	
	HP			4.8	5.6	6.2	6.8	7.5	8.3	9.1	11.0	12.6	14.6	16.5	18.6	20.9	
	RPM			930	990	1040	1090	1140	1185	1230	1320	1400	1480	1550	1620	1690	

Fig. 20—Portion of Rating Chart for Belt-driven Pumps
These charts have largely supplanted pump-rating curves for such pumps.

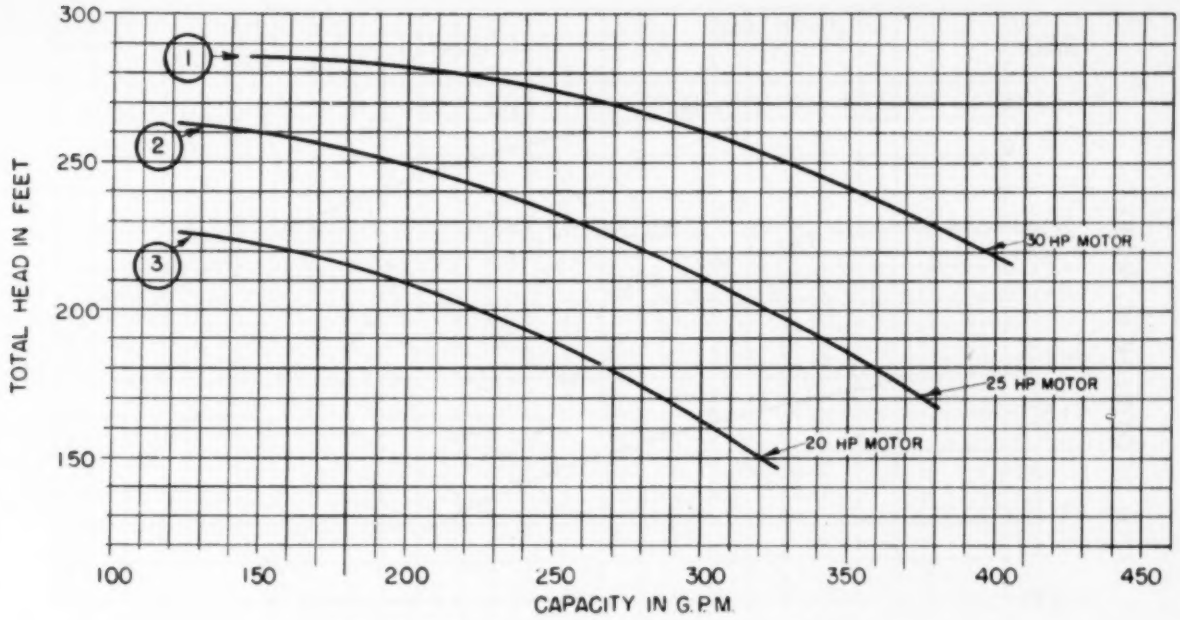


Fig. 21—Rating Curve of 2½ in. Motor Mounted Pump
This pump equipped with impellers that load up size of motor used.

the required NPSH gives permissible suction lift at sea level with 62°F water.

Design Constants and Formula

The design of centrifugal pumps is not an exact science. This is because of the many inter-related factors whose combined effect cannot be accurately foreseen and thus must be determined experimentally. The development of centrifugal pumps has been largely a result of the accumulation of data on the performance of specific designs in service and of experimental designs. Also, the result of research and experiences in other hydraulic fields, and the application of this information in the development of new designs. In analyzing data, centrifugal pump designers use various constants, formulas and relations. Only two of these are of any real interest to users of centrifugal pumps—namely, (1) Model Pump Relations and (2) Specific Speed.

Before discussing these, it should be pointed out that pumps are analyzed and compared basically at their so-called design conditions, that is under the head and capacity condition, at rated speed, at which maximum efficiency is obtained. Thus, for the pump whose characteristics is shown in Fig. 24, the design conditions would be 1480 GPM 136 feet total head at 1760 RPM.

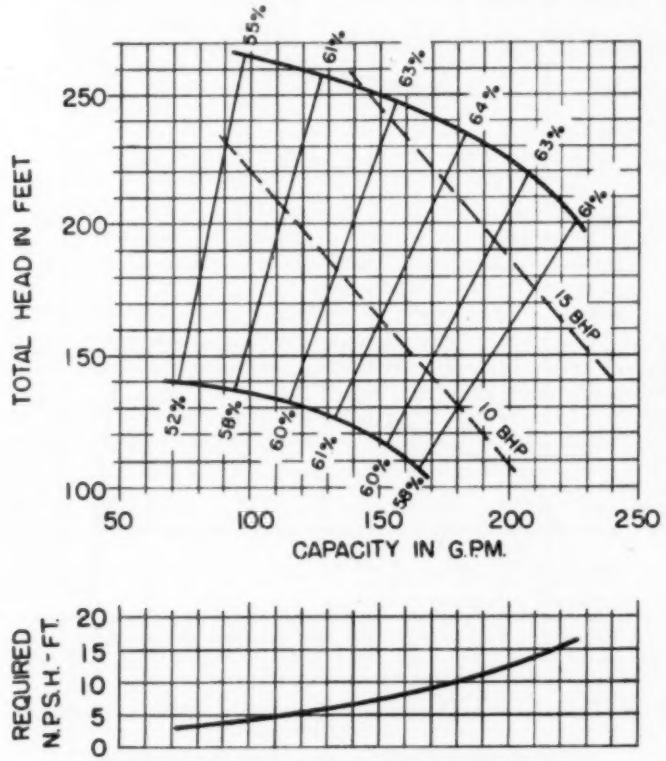


Fig. 22—Rating Curve of 2 in. Discharge 3500 R.P.M. Pump

Model Pumps

A Model Pump is a pump which on a smaller scale has the design features of a full size unit. To become a strict model, all linear dimensions of the model must be in the same proportion as the corresponding dimensions of the full size pump. The theoretical relationship of the performance of a model pump can be easily visualized by considering two pumps identically proportioned with one having twice the linear dimensions of the other.

The impeller of the smaller pump will be half the diameter of the larger and will therefore have to run at twice the rotative speed of the larger for the same peripheral velocity and thus for equal design head. Also the areas through the water ways of the smaller pump will be one half squared (i.e. ¼) the areas of the larger pump. Thus at equal velocities, the capacity of the smaller pump will be ¼ that of the larger pump. It therefore is apparent that for the same design head the interrelationship of exactly similar pumps would theoretically be—

$$f = \frac{L_a}{L_b} = \frac{n_b}{n_a} = \sqrt{\frac{Q_a}{Q_b}}$$

where f is the ratio or factor of the two pumps.
L_a and L_b are comparable dimensions of the two pumps.
n_a and n_b are the rotative speed of the two pumps
Q_a and Q_b are the capacities of the two pumps at comparable points on their characteristics.

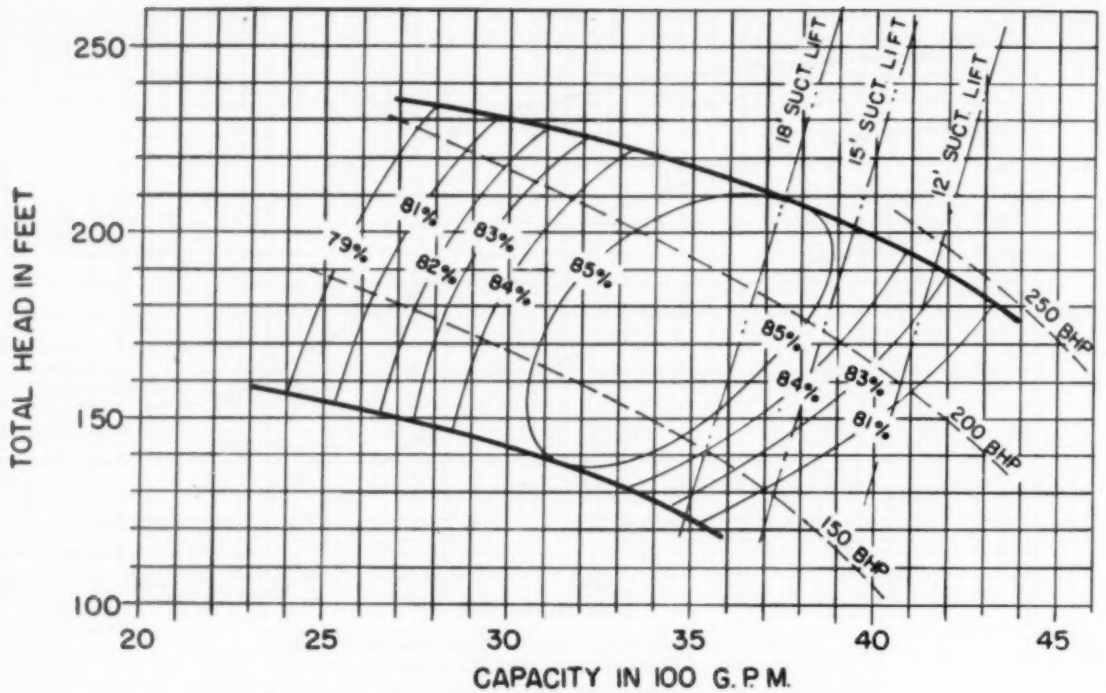


Fig. 23—Rating Curve of 10 in. Double Suction Single Stage Pump
Reveals wide range that can be covered by an impeller of single design when machining it to proper diameter for service at hand.

The above is based on the assumption that the two pumps are proportional in every way and that the same relative degree of interior smoothness is obtained in the two pumps. This is difficult of attainment, for the actual smoothness of castings will be approximately the same irrespective of size. Thus, the relative internal smoothness of a larger pump is greater than that of a smaller pump. This is reflected in the head losses in the pump waterways so the larger pump should produce a higher head than the smaller pump for points of similar capacity. Also as part of the quantity pumped leaks through the rings, this loss may not be in proportion in both sizes of pumps, thus affecting the net quantity delivered. Finally part of the power input goes into mechanical losses (bearings and stuffing boxes). While these mechanical losses will be roughly in proportion to the pump sizes, they will not be exactly proportional, thus resulting in a third discrepancy. In addition (especially in the production of a commercial line of pumps) it would not be found good mechanical design to make the shaft, casing thickness, thickness of impeller vanes, etc., of two pumps in exact proportion to their size factor. As a result it would be found in the comparison of the largest and smallest pumps of a closely homologous line of a commercial design that some difference in performance will occur and the magnitude of the difference will depend upon the size factor and the actual physical sizes of the two pumps. Centrifugal pump designers are therefore careful in making model pumps to use a size which will be close enough to the full size pump so that the results of the

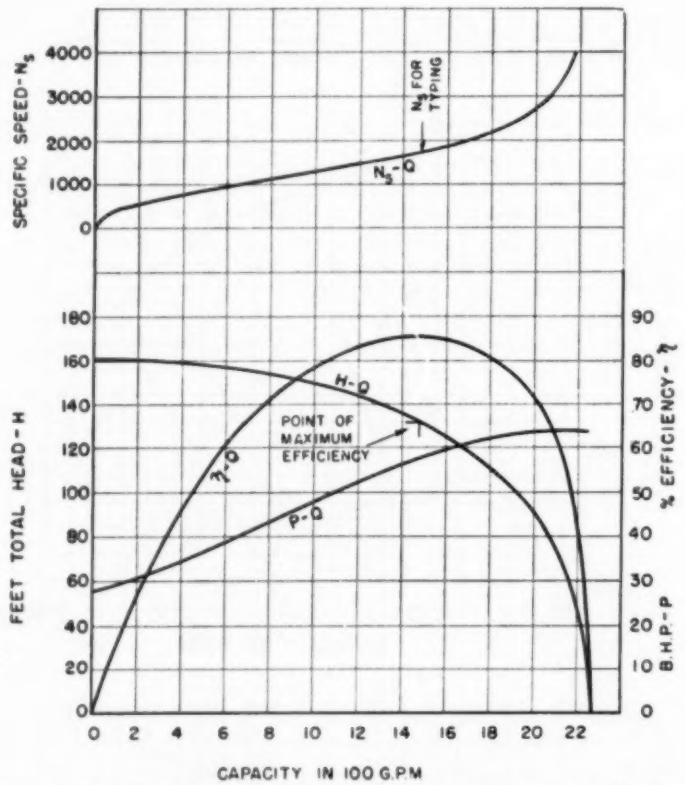


Fig. 24—Typical Pump Characteristic Curve with Auxiliary Specific Speed Curve Above

(For a 6 in. double-suction single-stage pump operating at constant speed of 1760 RPM—see text.)

* Figs. 25 and 26 are reproduced from "Standards of the Hydraulic Institute—Centrifugal Pump Section," by permission of the Hydraulic Institute, 90 West St., New York City.

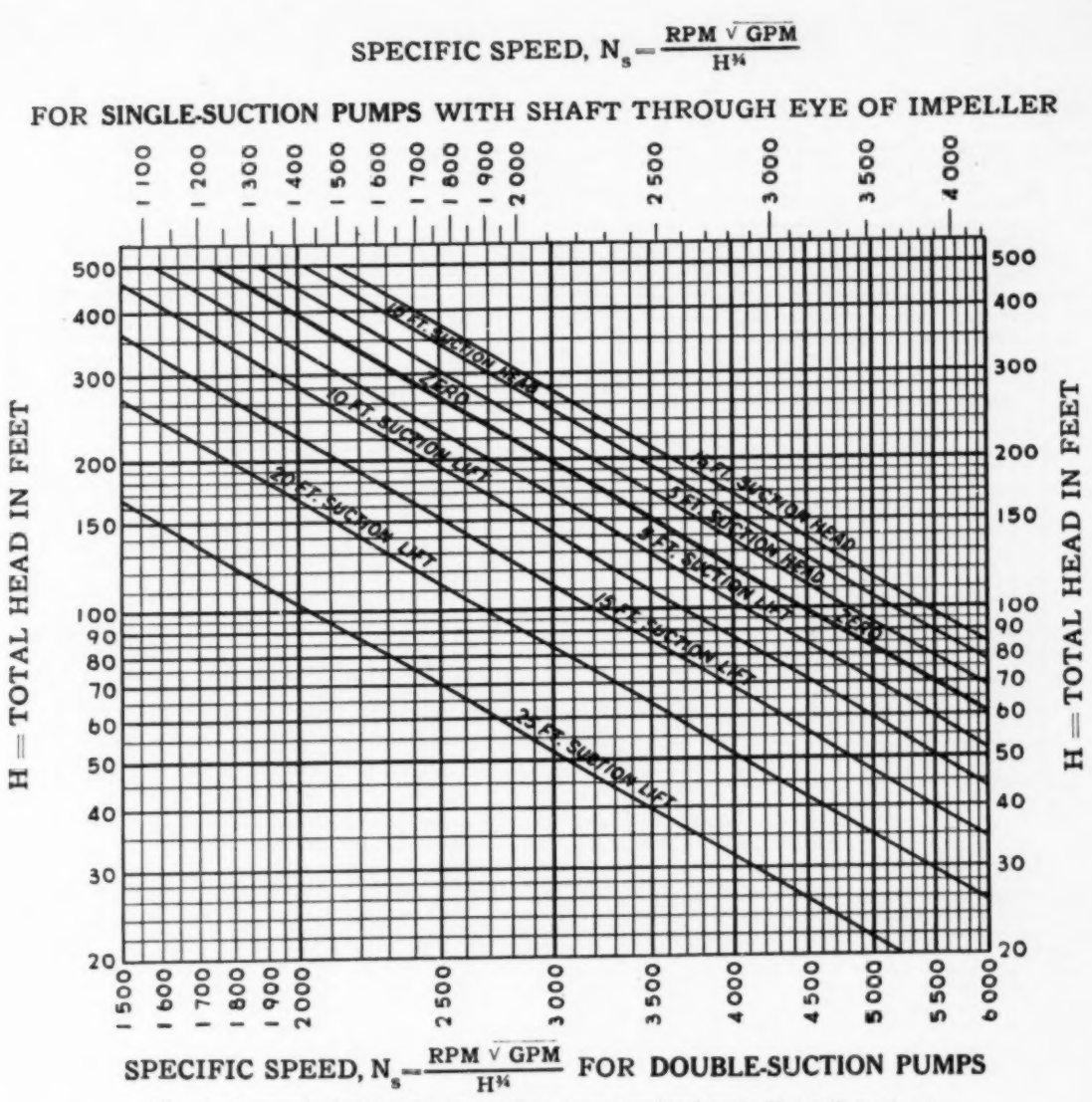


*Fig. 25—Commonly Used Specific Speed Limit Chart. Developed by the Hydraulic Institute**
(Application of this important chart for single stage pumps of true centrifugal type described in text.)

model will permit predicting reasonably closely the performance of the full size pump.

Model pumps have been used to prove within a reasonable degree of accuracy the performance of the full size unit for almost every case involving special large capacity centrifugal pumps built in recent years and the Test Code of the Hydraulic Institute covers the test procedure for such models.

Specific Speed

The basic definition of Specific Speed is that it is the speed in revolutions per minute at which a theoretical[1] and geometrically similar pump would run if proportioned to deliver 1 GPM against 1 foot total head with its best efficiency at these service conditions. It is therefore an index of the pump type, using the capacity and head obtained at the maximum efficiency point. It is sometimes desirable to determine the specific speed of a pump at a capacity and head other than that of best efficiency but such specific speed value should not be used as an index of the pump type.

It is desirable to consider the specific speed of a pump as a type number rather than the actual rotative speed of a 1 GPM 1 foot total head model pump because, in most cases, such a model pump, if made, would not deliver that capacity and head. For example a certain 18" discharge 20" suction double suction single stage volute pump delivers at best efficiency, 13,000 GPM 102 feet total head at 860 RPM with a 25" diameter impeller. Its theoretical 1 GPM 1 foot total head model would have a 0.56" diameter discharge opening, a 0.67" diameter suction opening, an 11/16" diameter impeller and would operate theoretically at 3050 RPM to deliver 1 GPM against 1 foot head. Such a model would be too small to give comparable hydraulic results.

The formula for determining specific speed is—

$$N_s = \frac{n \sqrt{Q}}{H^{3/4}}$$

where N_s = Specific Speed.
Q = GPM capacity at speed n and head H.
n = Rotative speed in R.P.M.
H = Total head per stage in feet.

The normal range in specific speeds encountered in single suction impeller designs is from 500 to 15,000 with approximate impeller profiles as indicated on Fig. 27. Basically the lower the specific speed, the higher the head that can be developed per stage by the pump.

For a given total head and suction lift condition, it has been found from experience that the specific speed of a pump should be below a certain value for successful operation. The Hydraulic Institute has issued specific speed charts, that are reproduced herewith. One, (Fig. 25)

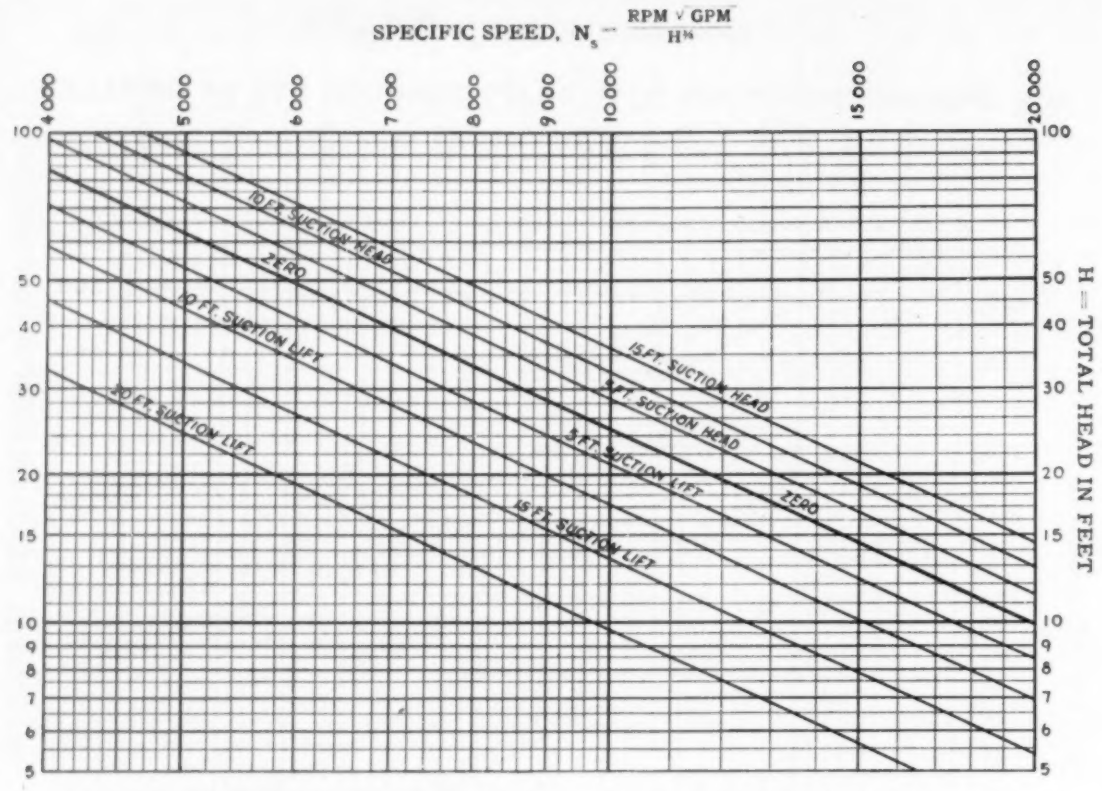


*Fig. 26—Another Specific Speed Limit Chart Developed by the Hydraulic Institute**
(This chart for single stage pumps of mixed-flow and axial-flow types.)

applies both to single stage double-suction pumps and to single stage single-suction pumps with a shaft through the eye of the impeller. The other (Fig. 26) applies to single stage single-suction mixed-flow and axial-flow pumps. (Both charts are based on 85° F water at sea level.)

These have been generally called "Specific Speed Limit Charts." It must be realized in using these charts that pumps built for the limit allowed are not necessarily the best design for the intended service and a lower specific speed type might be more economical, as in some other way preferable. It must also be realized that the individual pump design limits its application for both maximum head and for suction condition limitations. For example, the maximum recommended specific speed for a double suction single stage pump is 2130 for 200 feet total head and 15 feet suction lift. It does not follow that all double suction single stage pumps of 2130 specific speed type are suitable for operation at speeds which will cause them to develop 200 ft. total head at maximum efficiency; nor, that the pump, if suitable for operation at 200 ft. total head, is suitable for operation with 15 feet suction lift; nor, that a pump of

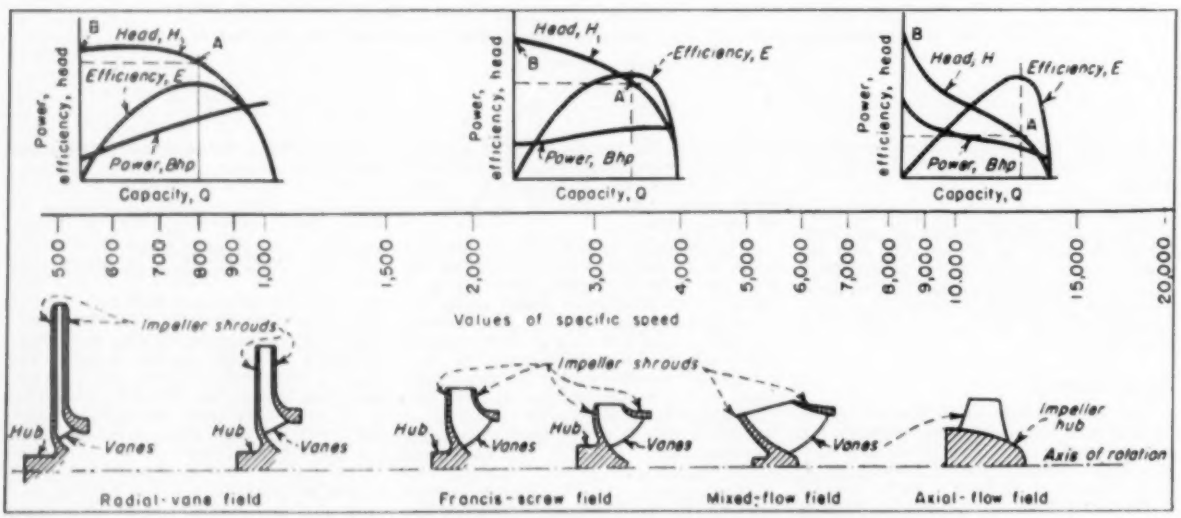


Fig. 27—Type Characteristics and Specific-Speed Scale for Impellers of Various Designs
These impellers of various profiles range from lowest specific-speed radial flow design on left to highest specific-speed design on extreme right. The specific scale applies to the impeller designs below and type characteristics above.

this type operating against 200 feet total head would on test only be found capable of operating on 15 feet maximum suction lift. These charts are intended to indicate only the maximum rotative speed which experience has so far shown a centrifugal pump can be designed with assurance of a reasonable and proper operation for the anticipated combination of operating conditions. Nothing on these charts suggests that the specific speed indicated corresponds to the point of maximum operating efficiency. Pumps are normally chosen on the basis of providing a design which will operate near their maximum efficiency points. Thus, even though the service conditions do not correspond with the design conditions, the specific speed value is sufficiently close to the specific speed of the design conditions. For example, Fig. 24 shows the characteristics of a 6" pump whose maximum efficiency is at 1480 GPM 132 ft. total head 1760 RPM and thus the *true* specific speed is 1740. This pump would normally be applied for a range of 1300 GPM 140 ft. total head to 1600 GPM 125 ft. total head, a range of specific speeds of 1590 to 1890, which varies about 10% from the actual type N_s.

No attempt should be made to compare pumps on the basis of their specific speeds except for their design conditions. The reason for this is apparent when it is noted that every centrifugal pump has specific speed values from 0 to infinity, as illustrated in Fig. 24, depending upon the particular point on the head capacity curve selected.

On Fig. 27 there is shown the type characteristics of a low specific speed pump, a medium specific speed pump and a high specific speed pump to illustrate how the shape of the pump characteristics change with impeller type. This is the major reason for the differences in the shape of pump characteristics. Some variation in the shape of the curves can be obtained in the design of the impeller and casing water ways, but the variation that can be thus obtained without adversely affecting the efficiency is relatively small.

Part 5—Determining Pumping System Needs

To obtain the desired results a centrifugal pump must have a characteristic suitable for operation in the system on which it is to be used. It is therefore necessary to first consider the characteristics of the system, and the definite needs, if a suitable pump is to be obtained. Usually it is a simple matter to determine the system characteristics; but, occasionally, a complicated system is encountered requiring analysis of parts of the system and then combining these to show the system as a whole.

As discussed in Part 2, the total operating head for a given capacity through a system is the algebraic sum of the static head from supply level to discharge level (H_{st}); the terminal pressure minus the suction pressure ($P_d - P_s$); all friction losses at this capacity (h_f); and the entrance and exit losses (h_i and h_e), all expressed in feet of the liquid being handled. The various elements and nomenclature are shown in Figure 29.

While the simplest system would be one with only static head, such a system could not be more than approached in practice because, in any actual system, there would be some friction losses. Should there be no static head component nor any difference in pressure on the suction and discharge liquid levels, as in Figure 28, the head would be entirely frictional.

Determining Friction Head

In determining allowance for friction heads in a system, it must always be remembered that the loss in the piping depends upon the roughness of the walls and this generally increases as the pipe ages. Thus, if the loss is calculated on the basis of new pipe and a pump is selected for the total head thus determined, it will not deliver its rated capacity through the system a few years later when the roughness has increased and the friction loss has increased.

It has become customary in estimating pipe friction, where extreme detailed study is not warranted, to use friction head values that would be expected when the pipe is 15 years old. Thus, most tables on pipe friction are based on Williams and Hazen values of C = 100. Practice in figuring allowance for losses in fitting varies. Some use "equivalent length of piping" while others use a percentage of the velocity head. Both methods require some exercise of judgment in relating specific fittings to known values. Recent publication of data by the Hydraulic Institute has been helpful to those using the $K \times V^2/2g$ method.

Using frictional values for C = 100 for the pipe and figuring the losses in fittings and valves on the K times velocity head basis, the head for the system shown in Figure 28 for a flow of 2000 GPM would be determined as illustrated in accompanying example.

EXAMPLE OF ESTIMATING FRICTION HEAD

Entrance loss—12" bell not well rounded—K = 0.5	0.25 ft.
12" long radius elbow—K = 0.2	0.10
20' of 12" pipe @ 1.49'/100' pipe	0.30
10" x 12" reducer—allow	0.10
8" gate valve—K = 0.2	0.51
8" swing check valve—allow K = 1.8	4.56
8" x 12" increaser—allow K = 0.30	.76
3000 feet of 12" pipe at 1.49'/100' pipe	44.70
2—12" long radius elbows K = 0.2	0.20
3—45° elbows K = 0.2	0.30
Exit loss—12" pipe—1 velocity head	0.50
Total losses	52.28 ft.
(Round off to—52.3 ft.)	

Of this 52.3 feet head, 45 feet is loss in the pipe and will vary according to the C value of the pipe. The remaining 7.3 feet is allowance for loss in valves and fittings and will vary only slightly with the age of the pipe.

Figuring the values for various other capacities, we would be able to plot the relation of the system head vs. capacity as shown on Figure 30 (identified by the notation of C = 100).

Without further analysis it would have appeared that, had a flow of 2000 GPM

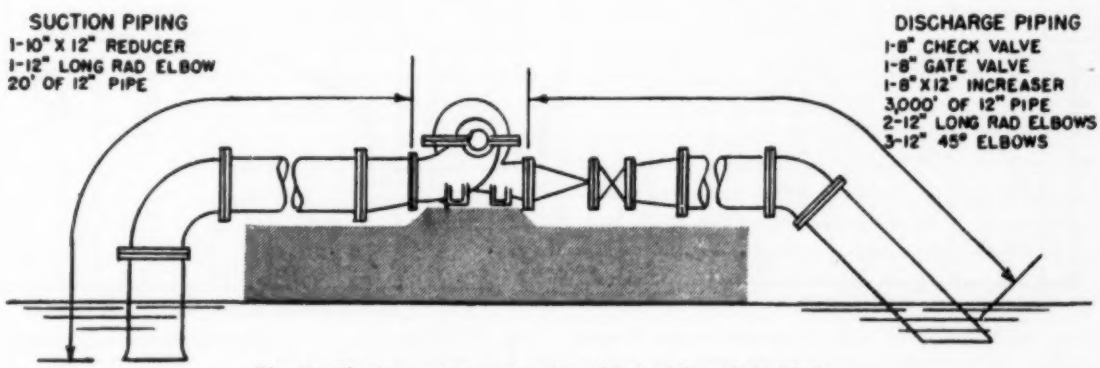


Fig. 28—Simple pumpage system in which head is entirely friction

been wanted, a good selection would be the pump with characteristic also shown on the same figure—Figure 30. Had the pipe been new, the friction loss in the pipe would have been less. If the condition of the pipe was such that a C = 130 might be expected, the pipe friction losses would be but 61.5% of those resulting with C = 100. For example, at 2000 GPM it would have been 45 × 0.615 or 27.7 feet, thus giving a total friction head, including that of the fittings, of 27.7 + 7.3 or 35.0 ft. The resulting system head curve on Figure 30, labeled C = 130. As will be noted, this would have resulted in more capacity being delivered by the pump with more power and a lower efficiency, namely, 2320 GPM, 46 feet total head and 82.5% efficiency.

If this installation was for a project where it was known that the water caused a slow increase in friction with increasing age of pipe, for example reaching a C value of 110 in 15 years or longer; or, if power costs were very high so that it was intended to keep the friction low by periodic cleaning of the pipe, then it would be advisable to select the pump for a lower head. Using the system head for C = 110 as the maximum to be encountered and at which 2000 GPM capacity is desired, the pump would have to be selected for 45′ total head. The same pump, if used with a smaller impeller for 2000 GPM, 45′ head would result in an initial efficiency of 82.5% for the system when the piping had a C of 130, and reaching about 84.5% when the C value had fallen to 110. If it were desired to obtain a better economy over the operating range, a larger pump would have to be used. The larger pump would have had a 10″ discharge, and a 10″ gate and a 10″ check valve would logically be used with smaller friction losses, so we would have to refigure the system getting the values shown in Figure 31.

Results With Two Pumps in Parallel

One of the most common pumping systems in which the head is all or nearly all friction is encountered in circulating pumps for surface condensers. These are generally complicated by the need of less water in winter when the water temperature is low than in summer when the water temperature is high. Generally, two pumps of equal capacity are used. Both are run to give the required capacity for summer operation and one is run alone

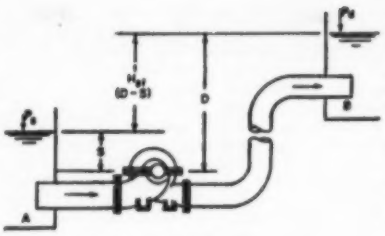


Fig. 29. General Formulas

Suction Head

$$h_s = S - h_{fs} - h_i + P_s$$

Discharge Head

$$h_d = D + h_{fd} + h_e + P_d$$

Total Head

$$H = h_d - h_s$$
$$= H_{st} + h_f + h_i + h_e + (P_d - P_s)$$

Net Positive Suction Head

$$NPSH = S - h_{fs} - h_i + P_s - P_{vp}$$

Nomenclature of Heads Not Shown on Diagrams

h_{fs} = friction head loss in suction line
h_{fd} = friction head loss in discharge line
h_f = total friction head loss from A to B
*h_i = entrance loss at A
*h_e = exit loss at B
P_{vp} = vapor press. liquid at pumping temp.

*Some engineers include these losses in h_{fs} and h_{fd}

All heads and pressures must be expressed in feet of liquid with proper algebraic signs. Pressures P_s, P_d and P_{vp} can be either in gage or absolute values but, in any case, must all be measured above the same datum.

To convert pressures in psi (pounds/sq. in.) to feet of liquid, multiply by 2.31 and divide by specific gravity of the liquid at pumping temperature.

in winter. In such an installation the head would be made up of losses through some piping and fittings carrying the capacity handled by one pump and losses through other piping, fittings, and the condenser which would be carrying the combined flow. Thus *the system head curve occurring with one pump running will not be the same as with two pumps running.* The losses for the individual pumps are shown by curve P_1 on Figure 32. Naturally, with 2 pumps running, twice the capacity flow through the condenser gives the same loss in the individual piping for each pump. This is shown by curve P_2. The loss in the condenser and in the piping and fittings in which the flow is the same as through the condenser is marked C. At any capacity the system head with one pump running is therefore the head shown on curve P_1 plus that shown in curve C. With two pumps running it is the head shown on curve P_2 plus that shown in curve C. If the loss in the individual piping (P_1 & P_2) is low, the resulting curves S_1 and S_2 are so close that only S_2 can be constructed and the discrepancy ignored.

In such a pumping problem it is desired that good efficiency be obtained both when two pumps are running and when one pump is running. Plotting curve S_2 against the capacity handled by each pump, we obtain the system curves shown on Figures 33 and 34. The problem for this installation is to select a pump to give good efficiency both at 1600 GPM 25 ft. thd. and at the capacity and head resulting at the intersection of the pump head-capacity curve and the system curve S_2. This generally requires the use of a larger pump than if the pump were selected merely for the 1600 GPM 25 ft. thd. condition. Figure 33 shows an ideal selection for such a problem with 82% pump efficiency obtained for both operating conditions. Figure 34 shows the results that would be obtained had a smaller pump size selected merely for the two pump operation been used. Although, in this case, the smaller pump has a flatter head capacity curve and more actual capacity would have been obtained with one pump operating, only 74.5% pump efficiency would have been obtained for this condition. Had this installation been one in which both pumps are normally operated all the time and two units had been installed instead of one larger unit in order to permit operation at reduced capacity if one unit is out of service for some reason, the selection shown in Figure 34 would have been preferable to that on Figure 33 as the efficiency at 1600 GPM 25 ft. thd. is better and the first cost would be lower.

It is to be noted that the system illustrated in Figure 32 indicates no static head, and is based on the assumption that the full syphon head is recovered. While syphons up to 25 ft. or higher are feasible, full recovery is rarely obtained. It should also be noted in discussing the system illustrated in Figure 32, that unless the

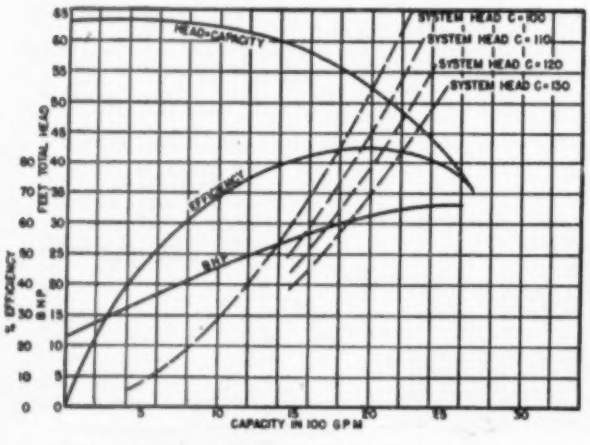


Fig. 30—System Head for fig. 29 installation with 8″ pump.

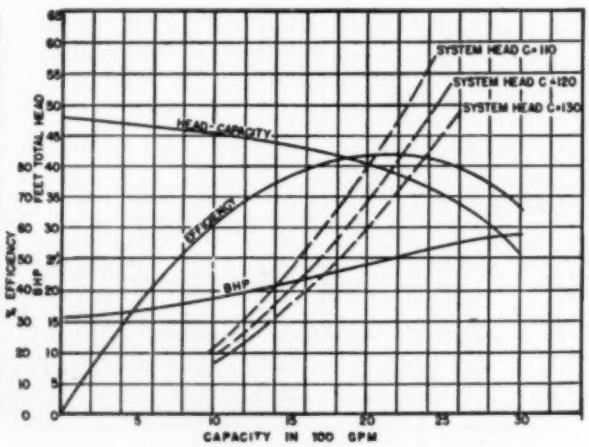


Fig. 31—System Head for fig. 29 installation with 10″ pump.

(Results obtainable with various roughness factors and comparison of results obtainable with an 8″ pump vs. the larger 10″ pump and improved performance thereby.)

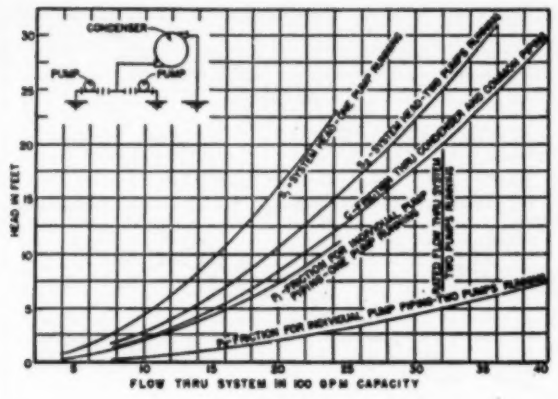


Fig. 32—Analysis of typical condenser installation with two pumps in parallel. Operating conditions shown for single and two pump operation.

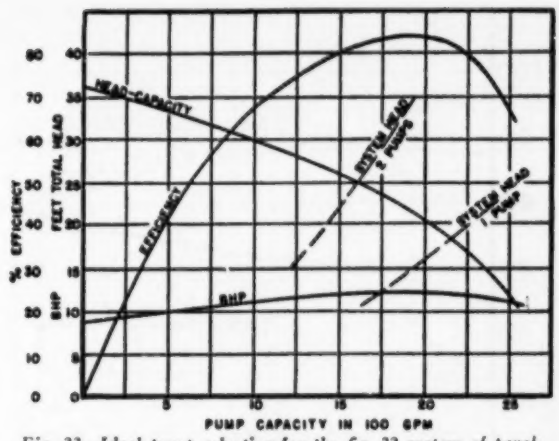


Fig. 33—Ideal pump selection for the fig. 32 system of parallel pumps if both single and dual pump operation are equally important.

piping and condenser water ways are primed before the pumps are started, the pumps will have to fill the piping and condenser before the syphon can be established. Thus, in the starting cycle, a static head equal to the syphon leg will be encountered just before the syphon is established, so the maximum starting head could be determined by adding the syphon leg as a static component to curves S_1 and S_2. To obtain a pump characteristic which will deliver sufficient capacity to establish the syphon without compromising the results to be obtained when the syphon has been established, is often impossible. Modern practice is to provide priming equipment, so the syphon loop can be evacuated, and the syphon established without making it necessary for the pump to overcome a high starting head.

When there is a static head, or its equivalent in pressure or both, included in the head the system head is the sum of these components and the friction head. Thus, for the system as show in Figure 35, the friction head losses would have been determined in curve form as shown on that figure and added to the static head, giving the system head indicated. Had the pipe been new with a coefficient of C = 130, very little increase in capacity would have resulted, as can be seen from the figure. Thus, the possible error in determining the friction loss becomes less important as the percentage of the friction head in the total becomes less.

Effects of Variable Static Head

At constant speed, the head developed by a centrifugal pump varies with the capacity delivered by the pump. Thus, if it is used on a system in which there is a variation in static head, a variation in the capacity delivered through the system will result. Frequently, when buying a pump for such an installation, a purchaser will calculate the friction at rated capacity, add it to the average static head and state that as the design head. In addition he will add the same friction head to the maximum and minimum static heads and give the resulting heads as the maximum and minimum operating heads that the pump will encounter in service. This practice neglects the change in friction with change in capacity and unnecessarily handicaps the manufacturer in selecting a suitable pump for the service. For example, in the installation shown in Figure 36 some purchasers would specify that the pump had to operate over a head range of 65 to 95 feet giving rated capacity of 250 GPM at 80 feet head. Thus the pump whose characteristic is shown on Figure 36 would have seemed to be unsatisfactory, while actually it will deliver 79% rated capacity at the maximum static head and 115% rated capacity at the minimum static head.

It is often advantageous to know what capacity will be delivered by a pump operating on a system as shown in Figure 36 in terms of static head. Naturally for any capacity this will be the total head on the pump minus the friction loss at that capacity. This can be plotted as shown by the dotted curve in Figure 36 and shows, for example, that the flow to the tank will be 244 GPM when the static head is 57 feet.

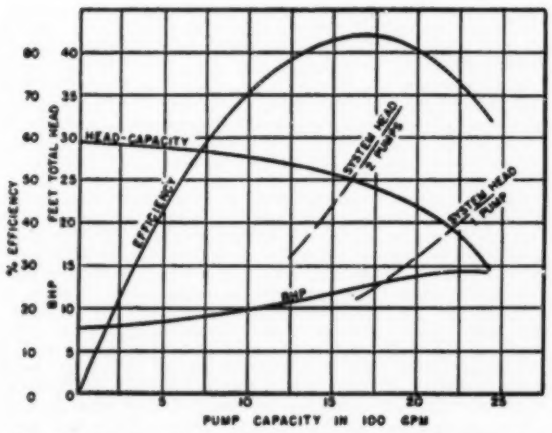


Fig. 34—Results obtainable with smaller pumps shown in fig. 33. Shows poor efficiency resulting during single pump operation.

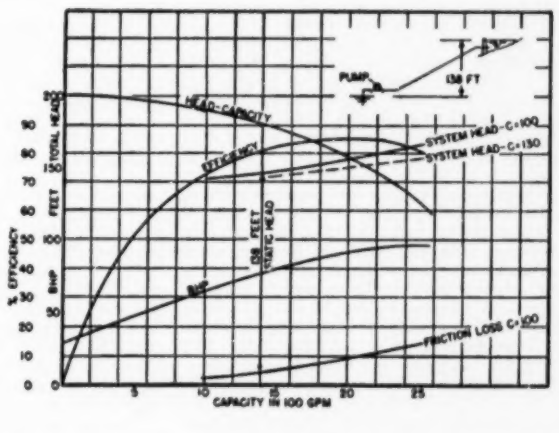


Fig. 35—When total head is mostly static error in computing friction losses or changes in friction has little effect.

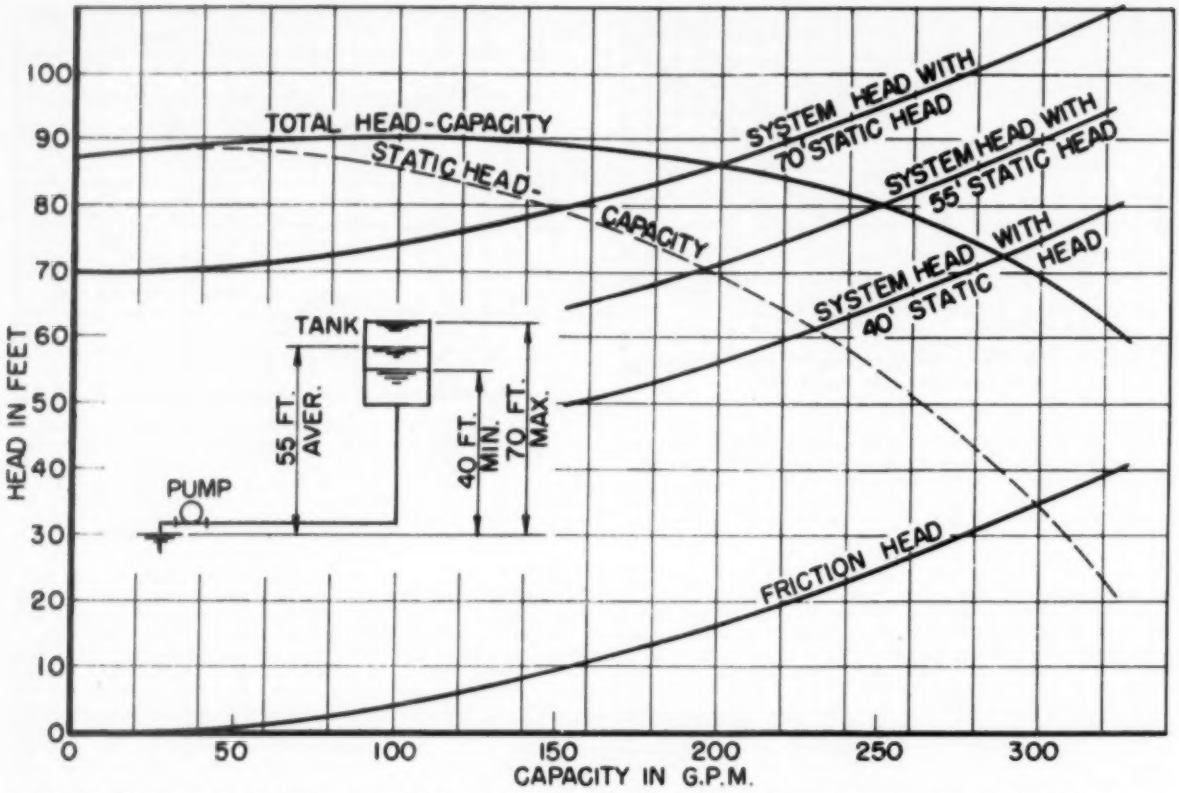


Fig. 36—Chart revealing importance of considering the change in friction head with pump capacity changes when delivering against a variable static head.
(Note that actual operating head may cover quite a range, with important efficiency changes resulting.)

Part 6—Determining Pump Delivery on Its System

Very often in the case of a plant or community located some distance from its source of water supply, the demand for water increases over a period of time and it becomes uneconomical, because of the frictional head loss with increased load, to continue to use the existing pipe line. If the original line is in good condition, the usual solution is to install a second line of a size that, in parallel with the existing line, will make for economical pumpage of the desired increase in the rates of pumpage. In such cases of two pipes operating in parallel, the flow through each line must be such that the friction head loss is the same for each. The proper approach to this problem is to plot the capacity vs. friction head loss for each line and then get the combined capacity vs. friction head loss for the two by adding together the capacity of each line at a number of points of equal head losses. For example, on Figure 37 there is indicated the head loss for a 10" line and the head loss for a parallel 12" line. With a 20 ft. friction head loss, the 10" line will have a flow of 1000 GPM while for the same loss in the 12" line the flow will be 1615 GPM. Thus 1000 + 1615 = (2615 GPM) will be the combined flow of the two lines with a head loss of 20 feet. Similarly the capacity for the two lines in parallel for equal head losses can be determined for a number of points and a curve showing combined capacity vs. head loss can be drawn, as is also shown in Figure 37.

In some systems, like a water works distribution system, it is desired to maintain a nearly constant pressure although the demand varies. To maintain an exactly constant pressure it would be necessary to vary the speed of the pump or pumps. It is rarely necessary to maintain the pressure exactly and some variation can be allowed. Most electric motor driven pumps for this service are therefore driven by constant speed electric motors with the result that the pressure will be dependent upon the head developed by the pump or pumps operating in parallel at the demand capacity. To produce a reasonably constant pressure for the full range of demand, pumps with head-capacity curves which have a shut-off head 10 to 20% more in excess of the head at design capacity are desired for such services.

Installation of divided flow or branch lines where the flow is not controlled, except to prevent overflowing of a tank or reservoir, usually involve two or possibly three branches. In case of the installation shown in Figure 38, it is obvious that no flow will go to tank A unless the friction head loss in the 4" line from C to tank B exceeds 10', the difference in static head for the two inlets. Considering branch B alone from point C, the system head has no static component and will be frictional head only. This is calculated and appears as curve B in Figure 39. The system head for branch A alone from point C has a 10 ft. static head component plus the friction in 500 feet of 4" line and works out to be curve A in Figure 39. The capacities for the two branches for equal system heads at point C can then be added together to give the system head of the two branches as a unit, which gives us curve (A + B) on Figure 39. As the friction loss in the piping from the supply to point C is common to both branches there would be no difficulty in establishing the friction head curve. This appears as curve D. As point C is 50 feet above the suction supply, the system head for the common system up to point C would be the friction head plus 50 feet. Adding to these head values, the head values on curve (A + B) we get our system head curve for the system, (A + B), on Figure 39. If the pump used for this

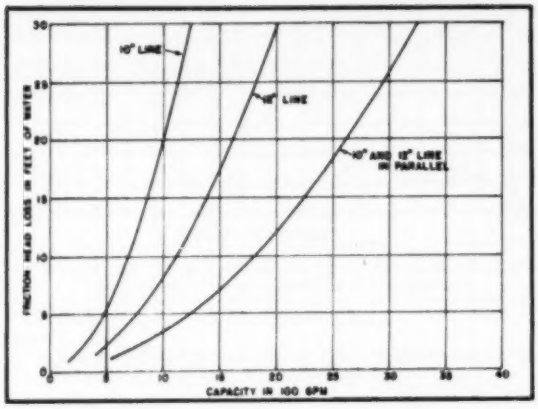


Fig. 37—Method of calculating the capacity vs. friction head for two pipe lines in parallel.

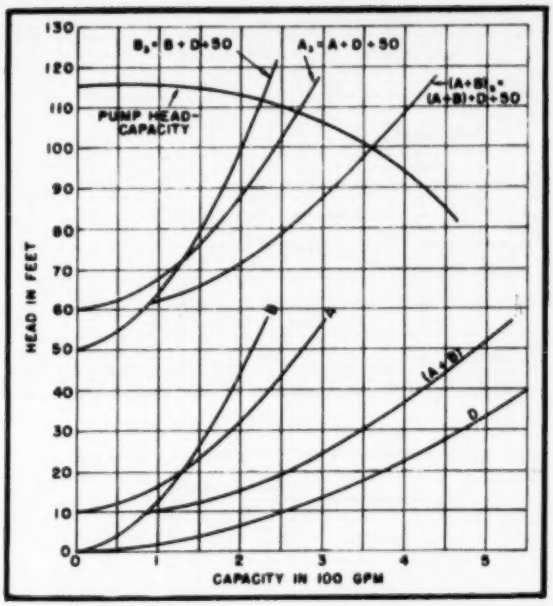


Fig. 39—Solution of problem presented in Figure 38.

service had the head-capacity characteristic H-Q on Figure 39, the resulting total flow would have been 358 GPM. Projecting down to curve (A + B) it would be seen that this capacity would have required a head at C of 31 feet. Projecting over to curves A and B would indicate 193 GPM would be going to tank A and 165 GPM to tank B.

If the two branches to the tanks had been equipped with valves actuated by some control so that they close when their respective tanks become full, there would be cases where the flow would be to either one of the tanks. The flow to tank A if the branch to tank B is shut off can be determined by constructing its system head curve A_s (by adding head values on curves A and D plus the 50' static head) and seeing where this curve A_s intersects the H-Q curve of the pump. Likewise B_s can be constructed to show what the flow to tank B would be if branch to tank A is shut off.

Had it been contemplated to use a pump which developed 61½ feet or less total head at 90 GPM capacity, the entire flow would have gone to tank B.

In many cases, especially those involving two or more pumps each with its own piping, valves, and fittings discharging into a common discharge line, the solution of a problem can be simplified by determining the head each pump will produce for its range in capacity at the point in the system where the piping becomes common. For example, in the system shown diagrammatically in Figure 40, the usual head capacity of pump #1 is shown on Figure 41. The friction loss from suction supply to point C is plotted (see curve h_f, Figure 41) and the system head (curve $h_f + s$, Figure 41,) for pump 1 from the suction supply to point C is thus determined. Subtracting the values on curve $h_f + s$ from those on the H-Q curve of the pump, we get curve H_e indicating the head that will be produced by pump #1 at point C depending upon the capacity it is delivering.

Two Types of Pumping Systems

Pumping systems can be of two types. The first is one in which the capacity is determined primarily by the demand, such as in water works distribution systems or in a boiler feed installation, with the flow being controlled by throttling which uses up any head developed by the pump over that required.

The second is one in which the flow is not throttled and the flow is that at which the head developed by the pumping equipment equals the head required to deliver that quantity through the system. For pumps to be operated in parallel on a throttled system, it is generally desirable that they have similar head capacity characteristics of the stable or rising type, in which only one capacity is delivered at any head from O to shut-off. Such characteristics are those shown in Figures 44 and 47. As mentioned above the increase in head from design capacity to shut-off should not be too high, as otherwise excessive pressure is developed at part capacity flows.

In a system in which it is desired to maintain a constant minimum pressure at the pumping plant with varying demand, it is usualy to have the design head of all the units the same and to have the shut-off heads of all units the same or approximately so. Thus, in case of flows less than the units in service will produce at rated head, the capacity delivered by each pump will be about the same percentage of the rated capacity. For example, in Figure 42 involving 2500 (pump A) and 5000 (pump B) GPM pumps operating in parallel, if the demand was 5500 GPM, the head developed by the two pumps would be 211 feet (21 feet

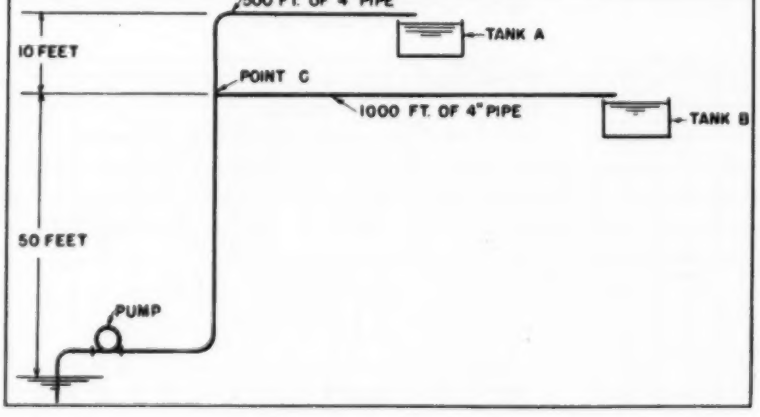


Fig. 38—Diagrammatic layout of system with two branches and uncontrolled flow (above) and

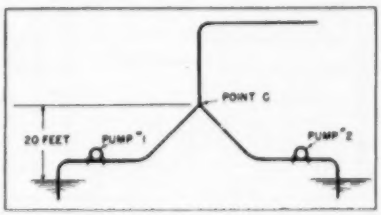
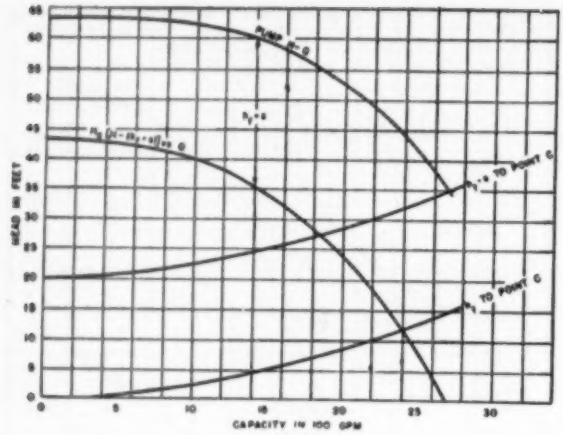


Fig. 40—A pumping problem involving two pumps, each with considerable individual piping discharging into a common line.



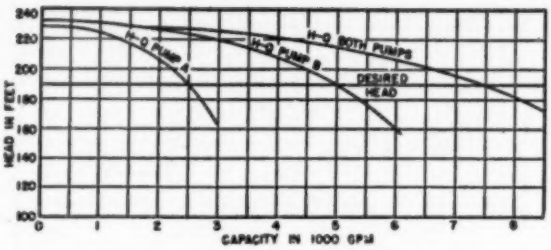


Fig. 41—Problems, as presented in Fig. 40, are solved by determining head available at common point.

Fig. 42—Head capacity characteristic determination for two pumps in parallel.

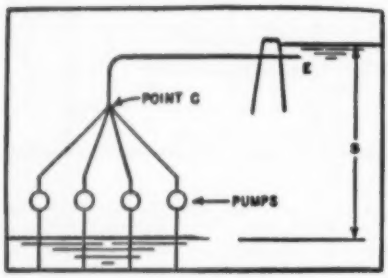
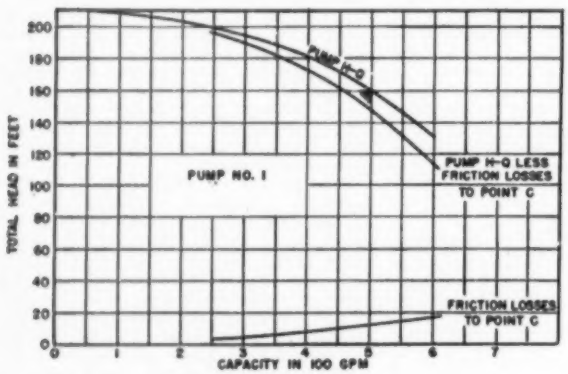


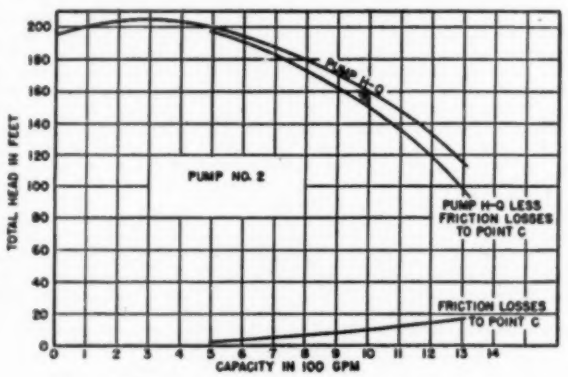
Fig. 43—Diagrammatic layout of a common problem, involving pumps with some individual piping discharging against a static head through a common discharge line.

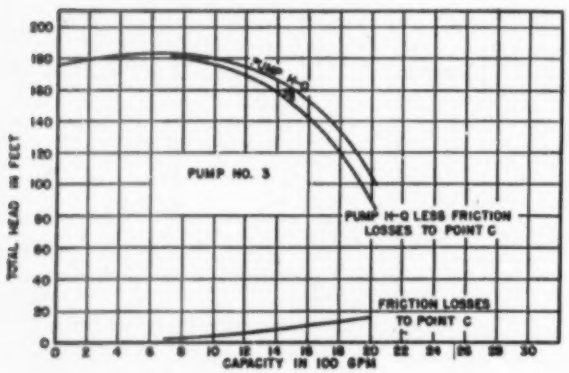
over that desired) and the capacity being delivered by pump A, would be 1800 GPM or 72% of rated while that being delivered by Pump B would be 3700 GPM or 74% of rated.

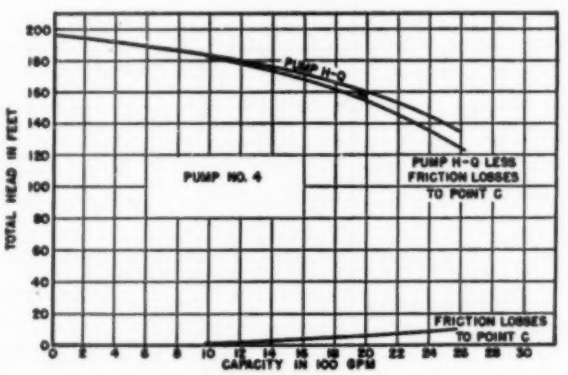
There are some throttled systems in which there is a long transmission line between the pumping station and the point at which a minimum pressure is to be maintained. In such cases, the reduction in pipe friction in the line with reduced flow will cause increased pressure at such reduced flow. Where this increased pressure is objectionable, the possible solution might be (1) throttling the excess head by some form of valve to keep a constant pressure (2) varying the speed of the pumps so that the required head is developed at the capacity demand (3) using one or more booster pumps in series with the pumps operating in parallel so the head developed by the pumps in service can be increased in steps as the capacity demand increases or (4) use of a number of pumps so that small increments of capacity can be obtained. In general in such cases the proper solution is that which is best economically and is therefore dependent in part upon the cost of power as well as the cost of personnel necessary for operation.

In the case of the second type of system in which the flow is not throttled and in which the capacity is that at which the head developed by the pumping system equals the head necessary to deliver that capacity through the system, pumps do not have to have similar characteristics in order to be operated in parallel. When buying additional pumps to operate in such a system, many purchasers make the mistake of requiring the additional









Figs. 44-47—Head-capacity characteristics of 4 pumps for system in Figure 43, also showing head-capacity with losses to C deducted.

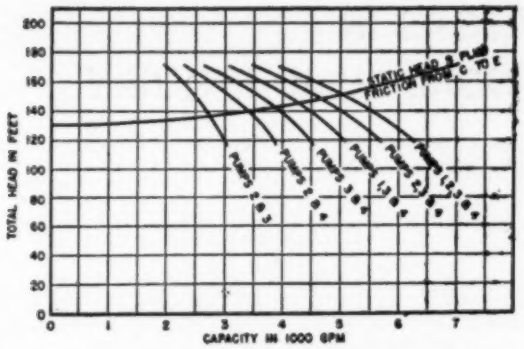


Fig. 48—System head and head-capacity curves of various combinations of pumps shown in Figs. 44 to 47.

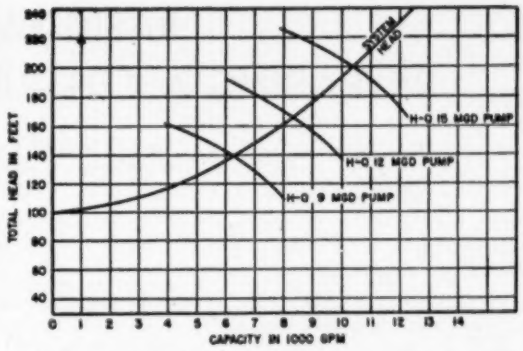


Fig. 49—When frictional component at maximum rated capacity is nearly same as static head, separate pumps spanning the capacity range desired are necessary for maximum economy.

pumps to have exactly similar characteristics to their existing units when it is not necessary.

For the system shown diagrammatically in Figure 43, the system head beyond Point C is indicated in Figure 48. The desired pumpage is from a 2500 to 5000 GPM rate. The four pumps whose characteristics are shown in Figures 44, 45, 46, and 47, are not similar but as the maximum head against which they will operate is 160 feet, all can be operated in parallel on this system. (Note the H-Q curves plotted on Figure 48 in combination with the other pumps have individual piping and fitting losses deducted.)

For systems like that just discussed, the most economical pump operation will be obtained when there is little variation in the system head as the capacity changes. In many installations the friction head is so large a component of the total head at maximum capacity, that pumps designed for specific capacities and heads are better in the long run than pumps in parallel which would operate at poor efficiency at other than designed head. For example, for the system whose system characteristics is shown in Figure 49 and in which a flow of 6250 to 10400 GPM is wanted, three separate pumps designed for 6250 GPM at 139 feet THd, 8530 GPM at 166 feet THd and 10400 GPM at 200 feet THd might be the proper solution.

In other cases where the head is practically all friction the solution may be a full capacity pump driven by a two or three speed motor. Figure 50 illustrates the characteristics of a pump driven by a two speed (1200 and 900 RPM) motor operating against a system head which is entirely friction. When operated at the lower speed the resulting capacity would be approximately ¾, while the pump efficiency remains practically the same. When pumps are driven by multi-speed motors, the capacities which can be obtained at lower speeds are dependent upon the speeds available so it is not always feasible to obtain the exact capacities desired. To obtain exact capacities a variable speed driver would have to be used.

Another possibility which is used considerably to increase the capacity of existing stations, is to install one or more booster pumps, either in the suction line to the main pumps, or in the common discharge line. For example, for the system illustrated in Figures 43 to 48, if conditions should change so the maximum demand at times will be 5900 GPM, one solution would be to have all four pumps discharge into a 5900 GPM 30 feet total head booster pump. Booster pumps are especially practical when the increase in head will cause considerable reduction in capacity of the main pumps.

The discussions in this article, while of a general nature, have used systems handling water as illustrations as that is the liquid most commonly used. The basic principles apply to systems handling other liquids as well. In some cases of liquids other than water, there are certain limitations, such as minimum pressures that must be maintained at any point in a system as when handling volatile liquids, which must also be checked when analyzing the system. Then too, it must be remembered that pumps with high specific speed impeller designs have steeper curves than pumps with low specific speed designs. Thus, in systems involving low heads for which a high specific speed type of pump will be used, a greater variation in percentage of total head can be met more efficiently than in systems involving high heads for which a low specific speed pump must be used. Occasionally, some low head system will require the use of a low speed type of pump in order to accomplish the desired operation.

There are a few systems in which there is a wide variation in head range with no fixed capacity being required at any specific head. Such a system occurs in dewatering a flooded mine. This is unlike most applications of centrifugal pumps, in that the total head against which the pump must work varies from approximately zero to a high maximum which occurs when the mine is almost clear of water.

A mine dewatering pump should be designed not for a single point of head and capacity, but rather, for the greatest possible capacity at all heads within the capacity of the motor. For installations involving final heads requiring multi-stage pumps, the best possible design is a "parallel-series" unit, with which the dewatering takes place almost twice as fast at the beginning as if the various stages were arranged to pump only in series, and yet, with the expenditure of the same power. Figure 51 shows the characteristics obtained in a special series—parallel mine pump.

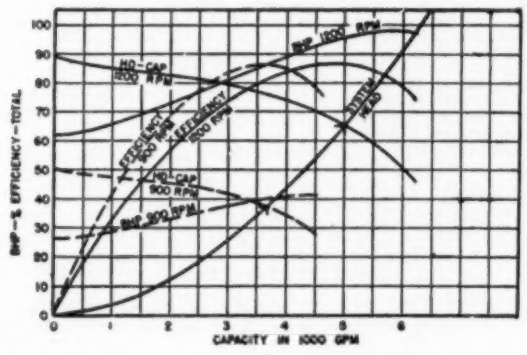


Fig. 50—Results obtainable with two-speed motor driven pump on a system which has entirely frictional head.

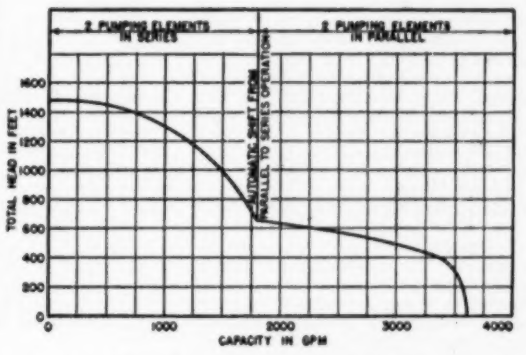

2 PUMPING ELEMENTS IN SERIES
2 PUMPING ELEMENTS IN PARALLEL
AUTOMATIC SHIFT FROM PARALLEL TO SERIES OPERATION
TOTAL HEAD IN FEET
CAPACITY IN GPM

Fig. 51—Head-capacity characteristics of a series—parallel mine pump where maximum capacity is desired at all heads.

BASIC FACTORS IN PREPARING A CENTRIFUGAL PUMP INQUIRY

by ROY CARTER and IGOR J. KARASSIK,
Worthington Corporation, Harrison, N.J.

The preceding series of six articles dealt with "Basic Factors in Centrifugal Pump Application." It extended beyond the mere term "application," since operation efficiencies, performance, and to a lesser extent maintenance, are also discussed.

In this series of three articles the same authors cover the "Basic Factors in Preparing a Centrifugal Pump Inquiry." They discuss the most essential data needed to intelligently select a centrifugal pump of proper type, design and operating characteristics for the conditions under which it is to operate.

Unless the pump bidder is supplied with such essential data it is impossible to make certain that the pump offered the purchaser will give minimum trouble, in operation and maintenance, and perform with a high degree of efficiency in power economy during a long life of non-obsolescence.

A careful study of these three articles is recommended to every prospective centrifugal pump purchaser.

IN order to achieve a satisfactory selection and application for a contemplated centrifugal pump installation it is highly essential to make a careful analysis of all the factors pertaining to it. It should be understood that it is impossible to present a complete survey of all these factors and therefore, experience and intimate contact with such installations are the only practical guides to a complete knowledge of the subject. Nevertheless, it is possible to outline the most essential data required to make an intelligent selection of a centrifugal pump for any given installation. Facts concerning these data should be ascertained before the inquiry for the centrifugal pumping equipment is prepared.

The essential data required to make a comprehensive analysis are summarized in Table I and are discussed more fully below, in the order in which they are listed.

1—Number of Units

As it will be seen presently, hydraulic conditions may in certain cases dictate the number of pumping units required to meet the total requirements. Nevertheless, the number of units selected for a given installation is primarily affected by reliability considerations. Thus, standby units are frequently necessary in order to prevent a dangerous interruption of service, or in cases where the life of the pump may be jeopardized by the severity of the service.

The choice between the use of a single pump for a given application and the installation of several pumps in parallel for the full demand is generally influenced by the nature of the expected load factor. When the demand is more or less constant, the tendency is to select a pump for the full capacity corresponding to the maximum demand, adding a slight margin as provision against pump wear. If, on the other hand, the load is of a fluctuating nature, two or more pumps may be operated in parallel. At periods of light load, one or more of the pumps can be taken off the line for more economical operation, since the remaining pumps will share the load at a more efficient capacity. It goes without saying that whenever two or more pumps are intended for parallel operation, this fact should be made known, as the hydraulic performance of the individual units may need to be made suitable for operation in parallel.

The capacity of individual pumps is frequently selected with the view towards economy of operation at the loads most frequently encountered. For instance in the event that the demand remains at 65% of the maximum capacity most of the time, two pumps, each designed for about 70% of maximum flow, could be installed. Thus for the greater portion of the time one pump alone would be able to carry the load. When the total required flow exceeds 65% of maximum, the second pump is put on the line, both pumps sharing the load and operating in parallel.

There may be exceptions to this general practice:

(a) When the total capacity is too low to be split up efficiently between two pumps, a single pump may have to be used, regardless of the nature of the load factor.

(b) When the maximum capacity is too great to permit the use of the most efficient pump or of the most economical operating speed, the capacity may be split up between two or more units, again regardless of the nature of the load factor.

(c) When the efficiency of operation is inconsequential—as when the service is very intermittent or when the pumps are turbine driven and use is made of the exhaust steam for process work or for heating. In this or similar cases first cost will generally determine the number of pumps to be used in the installation.

(d) To insure reliable operation under all conditions, it is the practice for some specific services where interruption or reduction in flow must not occur, to use two pumps for a given installation. Each pump is designed for the total maximum demand, with both operating in parallel at all times, even for part loads. The advantage of such an arrangement is that should one of the pumps become inoperative for any reason, the remaining unit can take up the full load by itself. There is however, a definite disadvantage to this scheme, in that it involves the constant operation of the pumps at capacities under 50% of their actual design conditions. Such operation generally shortens the overall life of the pumps, in addition to reducing the operating efficiency of the installation. A further disadvantage is that the head generated by a pump operating at 50% of its design capacity and be-

Table I

SUMMARY OF ESSENTIAL DATA
Required in Selection of Centrifugal Pumps*

1—NUMBER OF UNITS REQUIRED

2—NATURE OF THE LIQUID TO BE PUMPED
Is the liquid:
(a) Fresh or salt water, acid or alkali, oil, gasoline, slurry or paper stock?
(b) Cold or hot and if hot, at what temperature? What is the vapor pressure of the liquid at the pumping temperature?
(c) What is its specific gravity?
(d) Is it viscous or non-viscous?
(e) Clear and free from suspended foreign matter or dirty and gritty? If the latter, what is the size and nature of the solids, and are they abrasive? If the liquid is of a pulpy nature, what is the consistency expressed either in percentage or in lb per cubic foot of liquid? What is the suspended material?
(f) What is the chemical analysis, pH value, etc.? What are the expected variations of this analysis? If corrosive, what has been the past experience, both with successful materials and with unsatisfactory materials?

3—CAPACITY
What is the required capacity as well as the minimum and maximum amount of liquid the pump will ever be called upon to deliver?

4—SUCTION CONDITIONS
Is there:
(a) A suction lift?
(b) Or a suction head?
(c) What is the length and diameter of the suction pipe?

5—DISCHARGE CONDITIONS
(a) What is the static head? Is it constant or variable?
(b) What is the friction head?
(c) What is the maximum discharge pressure against which the pump must deliver the liquid?

6—TOTAL HEAD
Variations in items (4) and (5) will cause variations in the total head.

7—Is the service continuous or intermittent?

8—Is the pump to be installed in a horizontal or vertical position? If the latter—
(a) In a wet pit?
(b) In a dry pit?

9—What type of power is available to drive the pump and what are the characteristics of this power?

10—What space, weight or transportation limitations are involved?

11—Location of installation.
(a) Geographical location.
(b) Elevation above sea level.
(c) Indoor or outdoor installation.
(d) Range of ambient temperatures.

12—Are there any special requirements or marked preferences with respect to the design, construction or performance of the pump?

*Note: The first three items are covered in detail in this article. The balance will be covered in Part II of this series.

low, is greatly in excess of the required pressure and, therefore, this excess pressure must be throttled if the pump is operating at constant speed.

If more than one pump is used to provide the maximum demand and if a partial reduction in available capacity is permissible, the installation may not require a spare pump. In such a case, sufficient spare parts must be kept on hand to effect a rapid restoration of full available capacity. If, however, no reduction in available capacity can be permitted, it becomes necessary to provide a spare pump which can be put into service immediately upon failure or stoppage of one of the pumps. Since this substitution must provide against the interruption of the prime mover as well as for pump failure, it is the general practice to use a different source of power to drive the spare pump. Thus, if the normal operation is based on motor drive, the spare pump would be driven by an internal combustion engine or a steam turbine. The switch-over to the spare pump can be accomplished automatically in any one of several manners. The impulse for the controlling mechanism can be, for instance, the interruption of current in a solenoid operated pilot valve or the decrease of pressure in the discharge header.

2—Nature of the Liquid Pumped

(a)—The nature of the liquid pumped immediately determines to a certain extent the types of pumps most frequently used for the service involved. Naturally, the widest range of selections is available for water service, but even this can be broken down into fresh and salt water. The selection of materials for the latter service varies greatly from the point of view of first cost, length of life and customer's preference and experience. Apparently insignificant impurities in the liquid comprise a highly important factor in the selection of the proper materials. In the same manner, the nature of the liquid to be pumped will affect to a great extent not only the materials of the pump, but possibly even the mechanical construction best suited to the purpose, depending on whether the liquid is an acid, alkali or oil. For example, if the pump is to handle highly corrosive liquids, not only will the pump be built of corrosion-resisting material, but means must be made available to avoid leakage of the liquid out into the atmosphere through the stuffing box.

(b)—The temperature of the liquid to be handled is a *very* important factor. Obviously, pumps from a standard line of general service pumps have definite temperature limitations, so that higher temperatures immediately predicate the necessity of special materials, water cooled stuffing boxes or special mechanical features such as centerline support of the casing. Likewise, when extremely low temperatures prevail, such as in refrigerating brine service, the addition of nickel has been known to increase the impact resistance of cast iron at these temperatures.

Any wide variations in the operating temperatures should also be known, as they will affect the specific gravity and viscosity range of the liquid in question.

If the liquid in question is water, the vapor pressure at any given temperature can be easily determined from steam tables. If however, some other liquid is involved it is necessary that the vapor pressure at the pumping temperature be carefully noted, since it figures importantly in determining whether or not the prevailing suction conditions are satisfactory.

(c)—The specific gravity of the liquid to be handled must be known in order to determine the power consumption at the design conditions and to select the proper driver size. Furthermore, a pump inquiry frequently expresses the required discharge or net pressure in pounds per square inch, which must be converted into feet of the liquid handled at the temperature involved.*

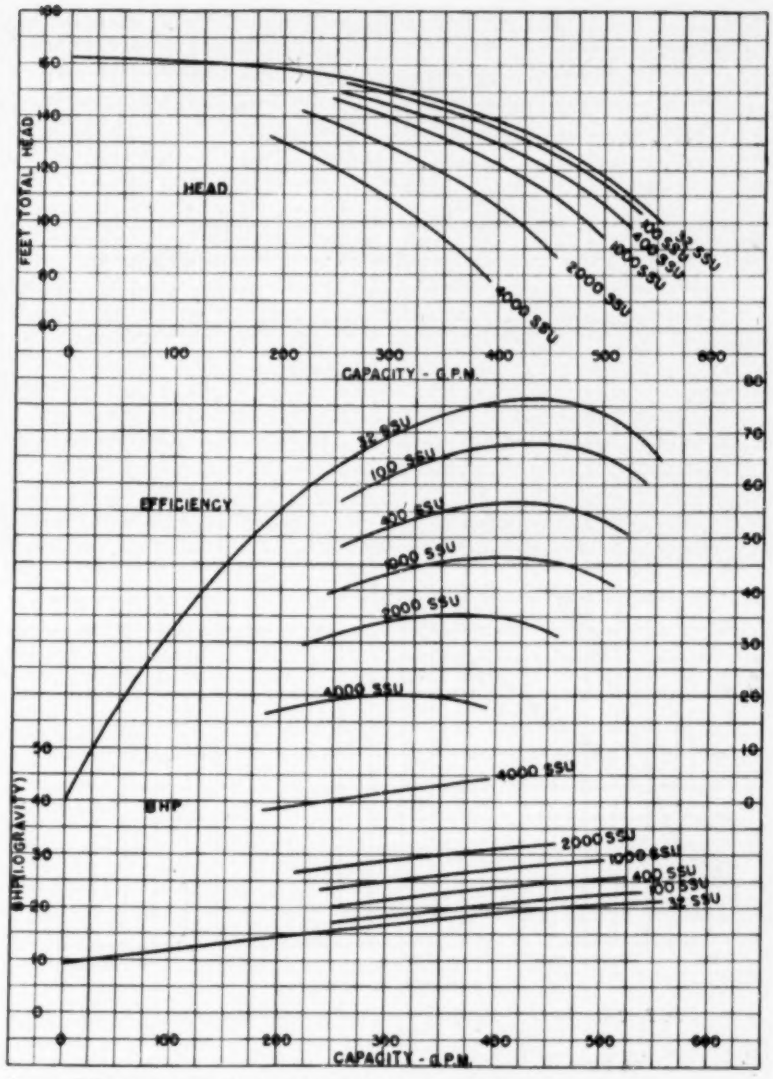


Fig. 1—Effects of change in viscosity of liquids on centrifugal pump performance.

* For conversion of pressure to feet of liquid, see "Basic Factors in Centrifugal Pump Application—Part I," by Messrs. Carter and Karassik.

(d)—When the viscosity of the liquid handled differs from that of water, the pump capacity, head and power consumption are all affected appreciably, so that correction factors must be applied by the designer to meet the required performance conditions. The effect of viscosity on pump performance is illustrated on Fig. 1, showing the performance of a specific centrifugal pump operated at constant speed and handling liquids of varying viscosity. The graph reveals that, with increasing viscosity pumping head and efficiency decrease for a given capacity.

(e)—The size and nature of the solids suspended in the liquid pumped will determine both the type of impeller best suited for the purpose and the materials to be used for pump construction. If the solids are very abrasive, an open impeller is generally used and, where the nature of the pumping job warrants it, special and more expensive wear-resisting materials may be applied. When solids reach a certain size, or are of a stringy nature, special non-clogging impellers, as used for sewage service, are required. An impeller of the non-clog type is shown as Fig. 3.

(f)—Special consideration should be given to the chemical components of the liquid if its corrosive or electrolytic properties are not readily apparent from the description of the liquid itself. Thus, pH of the water, which is a measure of its acidity or alkalinity, should always be stated if indications exist that the water is not neutral.

3—Required Capacity

The capacity required for the installation should be stated in U.S. gallons per minute at the pumping temperature. Any desired or imposed variation in the range of capacities should be clearly stated. It must be remembered that centrifugal pumps do not permit as great a flexibility in capacity variations,

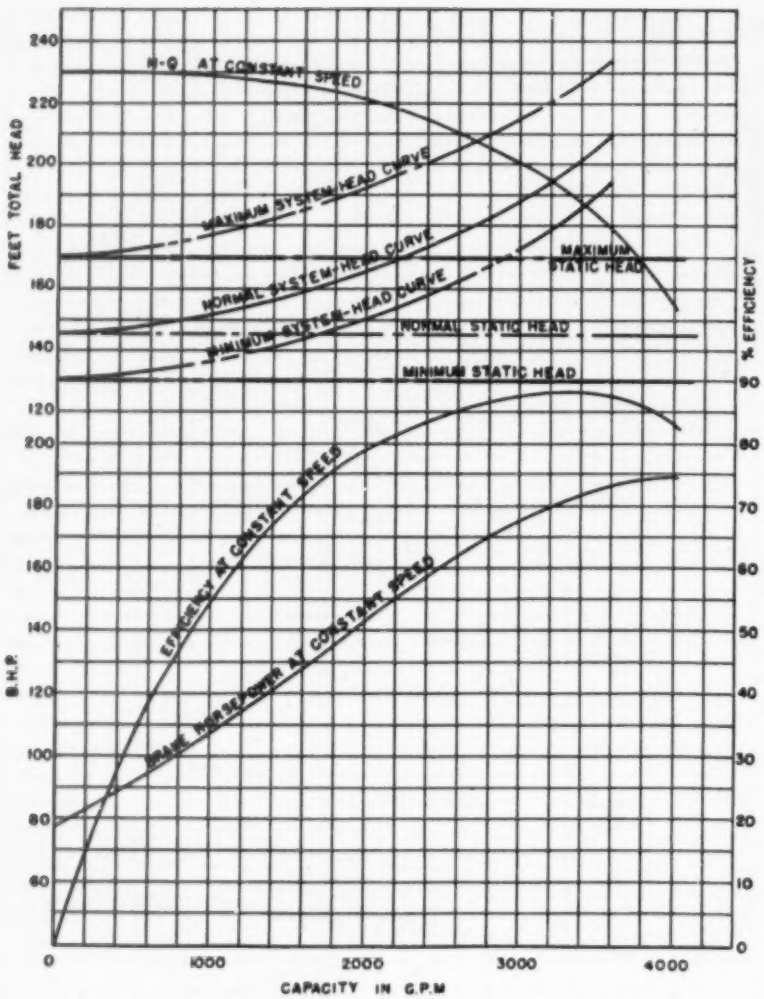


Fig. 2—The effects of changing static and system head on pump capacity.

without affecting pump efficiency, as the reciprocating steam pump. Furthermore, it is generally preferable to have the maximum efficiency of the pump occur at or near the normal capacity conditions. For instance, whenever the total head against which the pump must work includes a static head which varies considerably and the pump operates at constant speed, the capacity at which the pump will operate will also vary considerably as illustrated in Fig. 2.

While any centrifugal pump can run occasionally at a capacity considerably in excess of its rated capacity, this may not always be practical or permissible. The fact that an increase in capacity means a decrease in the head generated may prevent operation of the pump at emergency overloads if excess capacity was not included in the design and if the pump operates on a system head curve. This is so because the friction losses which make up part of the required head will increase with the capacity. Again, emergency over-capacity pumping may be prevented if the prevailing suction conditions leave no margin over those required for the normal rated capacity. Finally, if the power consumption increases with the capacity, as it does with the majority of centrifugal pumps, operation at capacities greater than originally expected may seriously overload the pump driver. Information as to the minimum capacity which may be encountered in operation is also of great importance. In certain cases, operation at extremely reduced capacities even for very short periods, presents a definite danger and means must be provided in the installation to avoid this. In other instances the only disadvantage accruing from operation at reduced capacities is poor economy and a thorough analysis of the problem may result in the installation of additional small units which would be operated during periods of light loads.

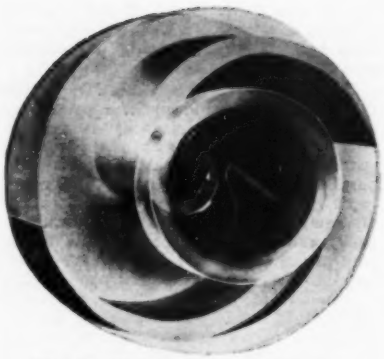


Fig. 3—Phantom view of the non-clog type of impeller required when the liquid contains large solids or stringy materials—this one a typical sewage type impeller.

Part II—Suction and Discharge Conditions; Total Head; Load Factor Characteristics of Driving Element; Axis of Rotation; Special Requirements, etc.

The first of this three part article presented a discussion of the effect of the number of pumps required, of the nature of the liquid to be pumped, and of the required capacity on the selection of the proper centrifugal pump for any given installation. We will continue with the analysis of the remaining factors which need be considered or determined before an inquiry for the required equipment is prepared.

4—Suction Conditions

It is *extremely* important to determine very accurately the suction conditions which will prevail in the proposed centrifugal pump installation. If the available net positive suction head (NPSH) is less than the minimum required by the pump selected at the desired capacity, the pump will be unable to meet its capacity design conditions. In addition, destructive cavitation may result from the unsatisfactory suction conditions and cause serious damage to the pump impeller, shortening the life of the equipment to an appreciable degree. A typical group of performance curves for a given pump operating under varying suction conditions is presented on Fig. 5.

If cold liquids are handled, it is necessary to know whether there will be head on the suction or whether the pump will operate on a suction lift. If the latter, what will be the maximum lift? In the event that the liquid is hot or under a pressure corresponding to or near its vapor pressure, the pump *must* be installed with head on suction and the available submergence must be made known. In all cases, it is advisable to determine separately the static difference between the liquid level and the pump centerline and the friction and entrance losses in the suction piping. If these losses have not been de-

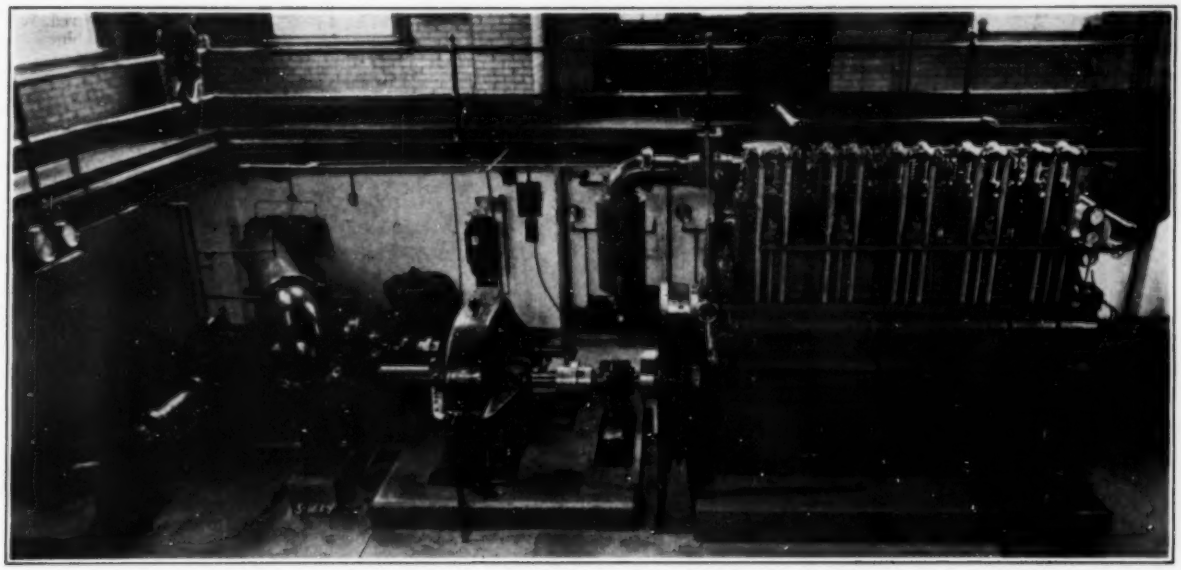


Fig. 4—Low speed Diesel engine driving centrifugal through speed step-up gear.

termined, it will generally suffice to describe accurately the suction layout, indicating all lengths and sizes of pipes, as well as fittings, valves, etc. (For effect of elevation above sea level, see item 11, "Location of Installation.")

5—Discharge Conditions

The discharge head for the design conditions should be stated with the understanding that it is generally composed of static elevation (or pressure) and frictional losses in the discharge piping and that any variations in the static head must be known in order to determine the maximum and the minimum head against which the pump is to operate. Specifying an excessive total head has actually the same effect as specifying excessive capacity. Since a centrifugal pump will always operate at the intersection of its head-capacity curve and of the system-head curve (*) a pump which develops an excess of head will, unless artificially throttled, deliver an excess in capacity as its curve will intersect the system-head curve at a greater flow.

By breaking up the discharge head into static and friction head, we are also able to tell whether the friction losses are excessive. If the piping to be used is too small, the required pump and its driver will be more expensive than necessary and the cost of operation greater than if the proper size pipe was used.

When the total cost involved is high and justifies an extremely detailed analysis, it is possible to determine the most overall economical size of pipe by comparing the sum of the amortization of initial pump, the driver and piping cost, plus the operating cost, versus cost of various pipe sizes.

In certain special applications, for short periods the pump may be required to develop discharge pressures in excess of the design conditions. A typical example is a condenser water circulating pump which is to be installed in a system utilizing a syphon effect. The head to be developed consists only of the frictional losses through the piping and through the condenser itself and is therefore of fairly low magnitude. However, in order to enable the condenser circulating pump to deliver water through the condenser, it is necessary to prime the system; in other words, to discharge water over the syphon. In this and similar cases the design of the pump must be such as to permit it to develop a head at shut-off considerably higher than the normal operating head.

In some condenser circulating pump installations the starting head required, before the syphon is established, might so affect the characteristic curve which must be developed that the normal operating head occurs at a point on the curve where the pump efficiency is relatively poor. However, in a syphon system it is generally possible to eliminate the higher starting head requirement by incorporating a vacuum producing device. This device, which is being increasingly employed, is connected to the top of the syphon, so that the air at the high point can be evacuated and the syphon established with the pump producing a head no greater than that required for normal operation. In many other cases, a little study and/or the installation of relatively inexpensive additional equipment will often simplify a problem of this nature.

* See "Basic Factors in Centrifugal Pump Application" (Part 5) by Messrs. Carter and Krassik.

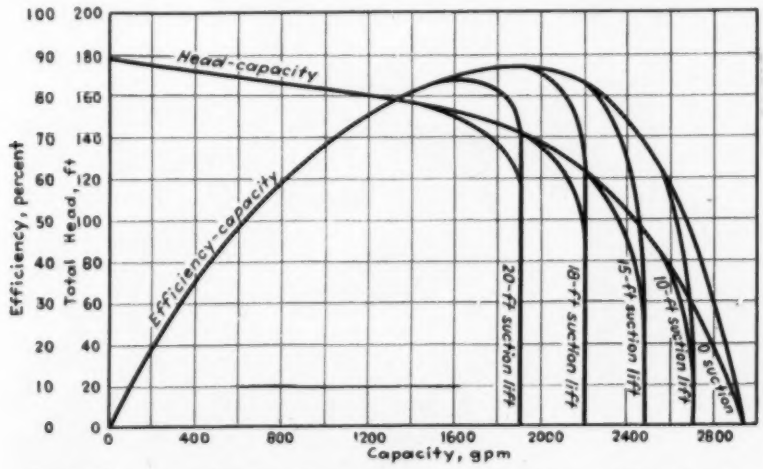


Fig. 5—Curves revealing that when suction lift against which a centrifugal pump operates is in excess of given values, both pump capacity and efficiency drop below normal.

6—Total Head

As defined in an earlier article by the writers ("Basic Factors in Centrifugal Pump Application," Part 2), the total head of a centrifugal pump is the difference between the discharge head and the suction head and is therefore the net energy imparted to the liquid by the pump. It should be remembered in determining the required total head that if variations are expected in both the suction and discharge conditions, similar variations will occur in the required total head. Furthermore, if the individual variations are, as usual, independent of each other, the possibility always exists that extremes in suction and discharge conditions may occur simultaneously. It is highly important, therefore, to determine *quite accurately* what the possible variations in required total head will be and to specify whatever information can be made available as to the interrelation of variations of the two elements which determine the total head.

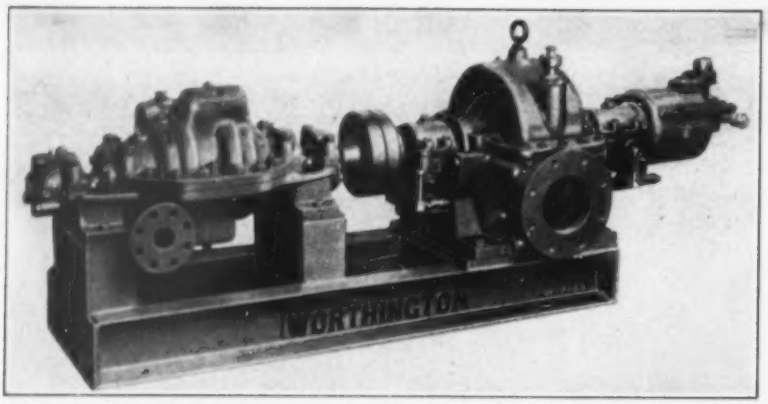


Fig. 6—Steam turbine drive, often more economical in industrial installations, is common practice in boiler feed water pump installations.

7—Load Factor

The expected load factor of the contemplated installation will play an important part in the selection of the best pump to be used. We have already seen in the first installment of this series (Part 1) to what extent the load factor will determine the number of units required to most effectively provide the capacity requirements. In addition, if the service is intermittent, it is unnecessary to use the most efficient pump available, the selection being generally made on the basis of least first cost. On the other hand, a pump intended for continuous service should be selected primarily on the basis of efficiency, reliability and long life.

8—Axis of Rotation

While the majority of centrifugal pumps are horizontal units, conditions are frequently encountered wherein a centrifugal pump with a vertical axis of rotation will prove to be more suitable. This is especially true in sewage pumping. Axial-flow propeller pumps and certain mixed-flow type pumps are frequently arranged for vertical operation. This results in a space saving installation and permits location of the pump insuring that the impeller is at all times under positive head, so that the pump is always primed. At the same time, the motor driver can be placed above the pump at a level sufficiently high to avoid accidental damage to the driver should the water level rise excessively. Sewage pumps of large size are prevalently installed in this manner and in a large measure the smaller size sewage pumps are also of vertical shaft design.

Vertical pumps can be arranged either for wet or dry pit installation. (See Figs. 7 and 8.) Since the *types* of pumps used for these two categories are quite different, it is very important to determine which of the two applications is preferable for any particular installation.

9—Characteristics of Driving Power

While modern centrifugal pumps are usually driven by electric motors, steam turbines or internal combustion engines, there are a great number of other types of drives as well as means of power transmission.

A centrifugal pump may be driven by:

1. Electric motor
2. Steam turbine
3. Gasoline engine
4. Diesel engine
5. Water turbine
6. Gas turbine

The driver may be connected to the pump by means of:

1. Direct drive through a coupling
2. Flat belt or multi-V-belt drive
3. Gear drive
4. Hydraulic coupling
5. Magnetic clutch or coupling

Finally, a centrifugal pump may be operated either:

1. At constant speed
2. At adjustable speed

A centrifugal pump, its drive and its method of operation should form an integral and harmonious unit. The specific application, and service for which the pump is intended, will dictate not only the choice of the pump itself but of its driver as well.

The electric motor is by far the most common type of driver for centrifugal pumps because electric power is usually the most economical and convenient source of energy. When steam is available at a lower cost than electric power, a steam turbine might be preferred. In many cases, standby pumps are turbine or Diesel driven as a protection against electric power failure. In some instances, the exhaust steam from the turbine is used for process work or for heating and thus the turbine acts as a reducing valve to produce low pressure steam.

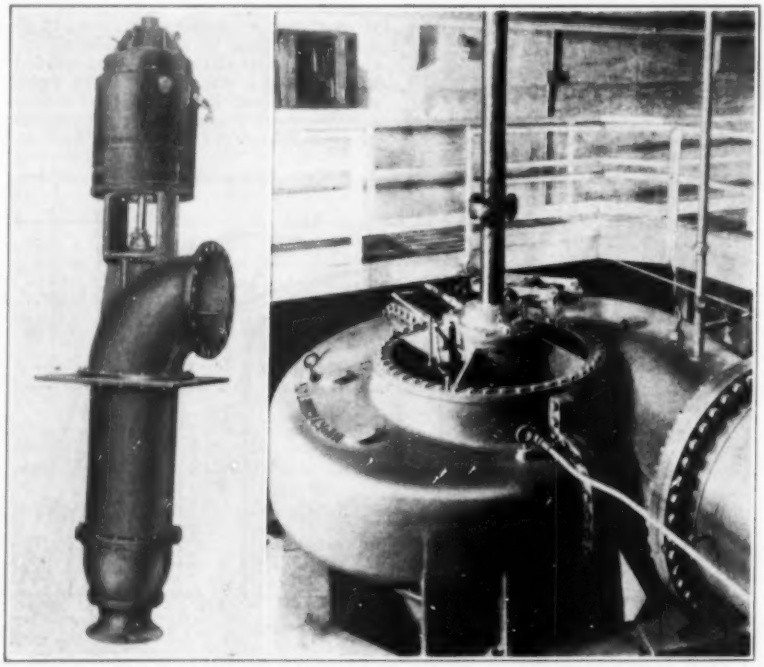
Gasoline or Diesel engines are used to drive centrifugal pumps mainly where there is no adequate electric power supply or where protection is required against failure of the electric power supply. Many dual driven centrifugal pumps are fitted with an electric motor at one end and a gasoline or Diesel engine at the other to take care of economy and also provide absolute reliability.

Diesel engines are more economical than gasoline engines in operation, but higher first cost is involved. Low head drainage and irrigation pumps handling large quantities of water require slow speed centrifugal pumps, and large HP, making the Diesel engine an excellent driver. Dual-fuel Diesels, utilizing sludge digestion gas and/or fuel oil, are prevalently employed in modern sewage treatment plants.

Water turbine drives have a limited application where a large supply of water is available as a cheap source of energy. As to gas-turbines, their use is still extremely limited, but indications are that applications will grow rapidly as the art of gas turbine design progresses.

Direct connection between a pump and its driver is generally preferred. However, centrifugal pumps are frequently belt driven when it is necessary or desired to use a driver—such as an engine or electric motor—having a rated speed other than that required by the centrifugal pump. Such an arrangement is also used when space requirements make it impossible to connect the pump and its driver in tandem and when they must be mounted alongside of one another.

Gears are used to step the driver speed up or down for the same reasons that belt drives are used. Thus for instance, gears



Figs. 7 and 8—Vertical wet-well pump on left operates submerged. Dry-pit vertical pump on right prevalently used in sewage plants, particularly the larger plants.

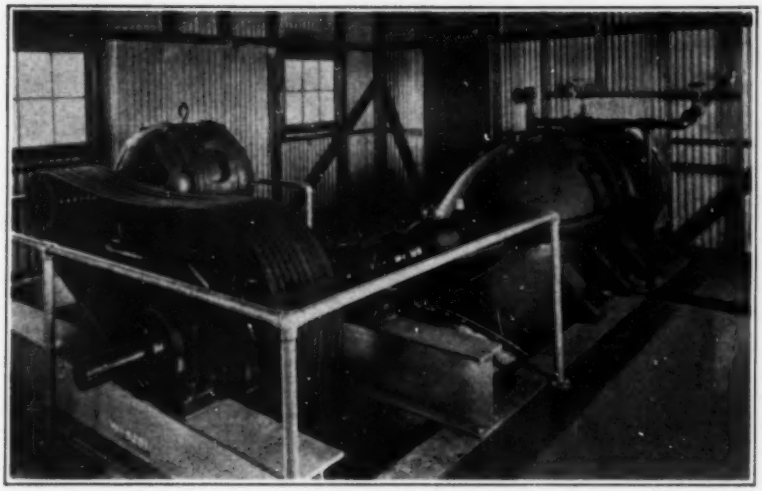


Fig. 9—Propeller type 42" pump with motor and multi-V-drive. Used in drainage, irrigation, and storm-water pumping. New Orleans has many of this type.

are frequently used with turbine drive in order to retain the high speeds conducive to low turbine water rates regardless of the low speed that may be required at the pump. On the other hand, it is quite common to use a separate gear between a Diesel engine and a centrifugal pump in order to step up the relatively low speeds of these engines.

Hydraulic and magnetic couplings are mainly used in order to obtain variable speed at the centrifugal pump while operating the driver at constant speed.

10—Space and Weight Limitations

It is sometimes necessary to install a pump in very cramped quarters and vertical pumps are usually preferred in such cases, as they take up only a small fraction of the floor space required by a horizontal pump of equal capacity. As an alternate, it is possible to select a pump operating at the highest speed compatible with the conditions of service, since this also serves to reduce space requirements. Although the use of close-coupled pumps (Fig. 11) was introduced primarily from consideration of first-cost economy, the application of such pumps presents very definite space-saving advantages. Finally, in a number of cases, the use of horizontal pumps with bottom suction (Fig. 13) may simplify considerably the problem of spacing and suction piping accommodation.

In general, the weight of the pump is a matter of no special importance, but aboard ships, for instance, weight is a deciding factor. For this reason, it is the practice in navy and merchant marine installations to use extremely high speed units of special design, operating at speeds up to 7500 rpm, and generally turbine driven. The pump design itself is directed towards the elimination of excessive weight through the use of lighter but stronger materials and the cutting away of all metal which can be dispensed with.

The facilities available for transportation should be outlined if there is anything unusual about them. Sometimes it is a long journey from the factory where a pump is built to the place where it is needed and it may be that over a part of this journey the transportation facilities are poor. Cases arise where horses and mules must be depended upon and where all freight must be carried on pack saddles. For transportation over such routes, pumps must be supplied which are light in weight and which are of sectionalized construction so that no single part is too heavy for horse or mule back.

In others cases a pump must be brought to its ultimate destination through tunnels or shafts of limited dimensions and the pump selection must be made with such restrictions in mind. All such limitations must be carefully listed lest a pump fully built may prove to be deliverable short of its installation point.

11—Location of Installation

The geographical as well as immediate location of the installation has a great bearing on proper pump selection and on its maintenance.

The elevation above sea level affects the pump in that there is a decrease in atmospheric pressure of about 1 in. of mercury per 1000 feet of elevation.* At at elevation of 4000 feet, therefore, the atmospheric pressure is 4 in. mercury or about 4.5 feet less at sea level. This means that a centrifugal pump can handle 4.5 feet less suction lift than at sea level.

* See "Basic Factors in Centrifugal Pump Application" by Messrs. Carter and Karassik, (Part I, Fig. 3).

The geographical location must also be taken into consideration when spare parts are to be recommended, since a pump which is to operate in an out-of-the-way place should be supplied with sufficient of the more important spare parts to avoid interruption of service if parts become worn and cannot be readily replaced. As a matter of fact this same recommendation applies in general, regardless of location of the installation. An adequate supply of spare parts is less expensive than extra stand-by pumping units.

The immediate surroundings of a pump will affect the accessibility after installation. It hardly needs saying that a pump located in a cramped or dirty and wet or poorly lighted position will surely be neglected by the operators, will not give satisfactory service and will be difficult to inspect, dismantle and repair.

12—Special Requirements

This factor must perforce cover a "multitude of sins." It is highly important that the pump manufacturer be made familiar with any special requirements and preferences of the personnel which is to be responsible for operation and maintenance of the pumping equipment. Some of these preferences may be based on insufficient knowledge of the most modern practices and equipment, but they may as likely originate from experience with pumps operating under the same or similar conditions that the new pumps will have to meet. Much valuable miscellaneous information may be made available to the pump manufacturer, information which will enable him to furnish that type of equipment which will give the longest and most reliable service.

The customer's recommendations, however, should be limited to the user's experience with pumps operating under similar conditions rather than form a list of his preferences, lest such preferences result in the purchase of *very special* and expensive equipment. Whenever the manufacturer's standard design and construction can be used, it is preferable to especially built units, both from the point of view of the original cost and from that of obtaining repair parts in later times.

In addition, it is necessary to take into serious consideration the expected ultimate life of the installation. If the design and materials of construction of centrifugal pumps are selected on a life expectancy

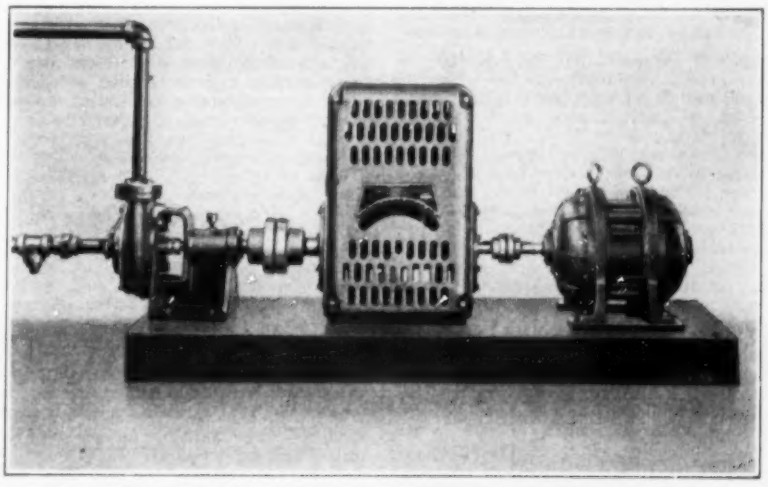


Fig. 10—Vari-speed drive unit between constant speed motor and pump. Wide variation in pump output obtainable by varying speed ratio through this unit.

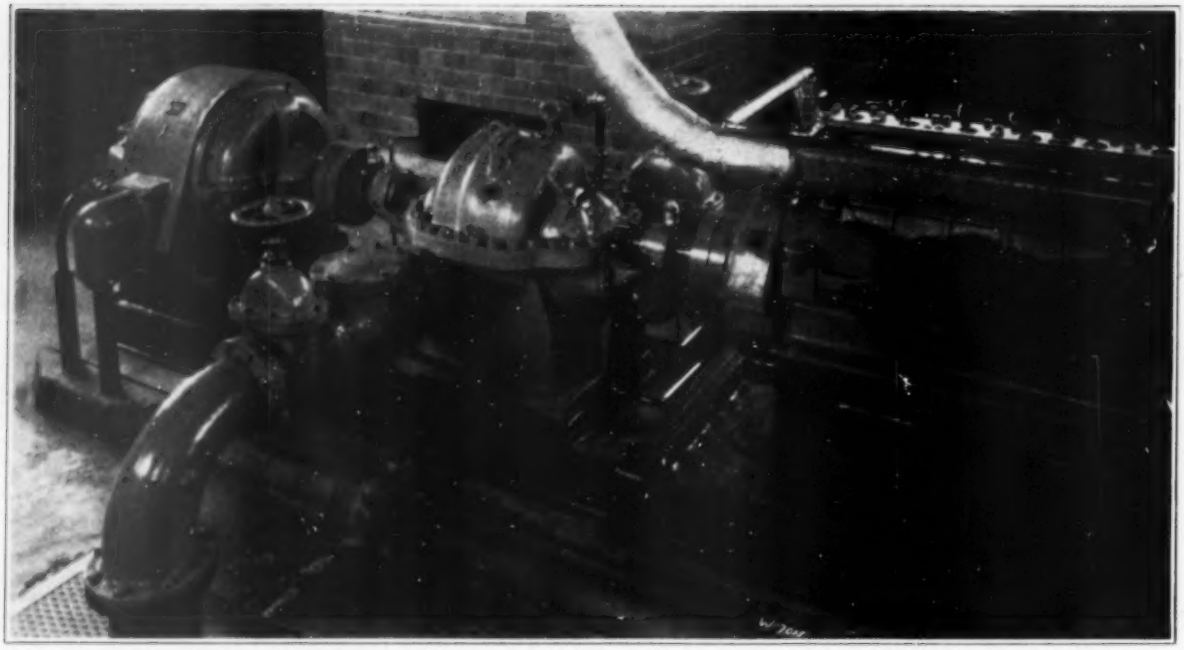


Fig. 12—Dual power drive centrifugal pump installation insures dependable service in case of power failure.

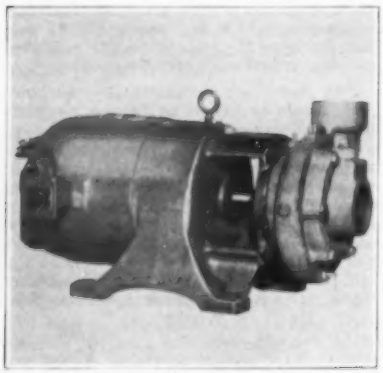
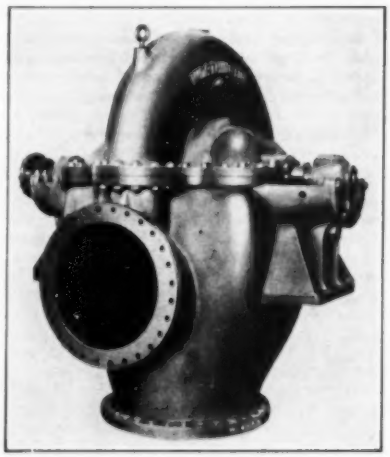


Fig. 11—Inexpensive design of package-style utility pump unit. Close coupled pump-motor combination on common frame.

Fig. 13—Horizontal drive centrifugal with suction intake entering at bottom of pump is termed bottom-suction pump.



much in excess of the life expectancy of the process or installation for which the equipment is intended, the original cost of the latter will be out of proportion. In other words, while it is a short-sighted policy to purchase equipment with a twelve month life for an installation designed to last fifteen years, it is just as wasteful to buy a pump to last twenty years if a temporary six month use only is contemplated.

Certain applications involving pump installations in office buildings, hospitals, etc., have special requirements relative to quietness of operation. These requirements should be listed on the inquiry in terms of permissible sound levels expressed in decibels. It is not advisable, however, to specify a specific maximum speed of operation to achieve the required quietness inasmuch as the selection of low speed centrifugal pumps does not in any way assure quietness of operation. Since every service condition has a best rotative speed for hydraulic correctness of application, a speed lower than the correct hydraulic speed is more likely to be hydraulically noisy than not.

Part III—Requirements in Specific Services

In the preceding two articles dealing with effective preparation of centrifugal pump inquiries we presented in a general manner the information which should be collected, with regard to a contemplated centrifugal pump installation, in order to prepare an inquiry which will facilitate recommendation or selection of pumping equipment possessing overall characteristics most suitable for the requirements to be met.

While all the factors outlined in those two articles should be properly investigated during the analysis of the installation, not all of them have an equal importance for the various services under which centrifugal pump applications can be classified. In order to illustrate these differences in the order of importance, there has been selected a group of representative services most commonly encountered in water and sewage works installations.

In the first article the most important points to be examined have been listed for each of these services. As most pumps are constant speed motor drive, except for one item these lists have been prepared with the general thought of this type of drive. Naturally if a variable speed drive is used the operating speed can be adjusted to allow the unit to cover a much wider range of conditions than feasible with a constant speed drive. Except for the one item, i.e.,

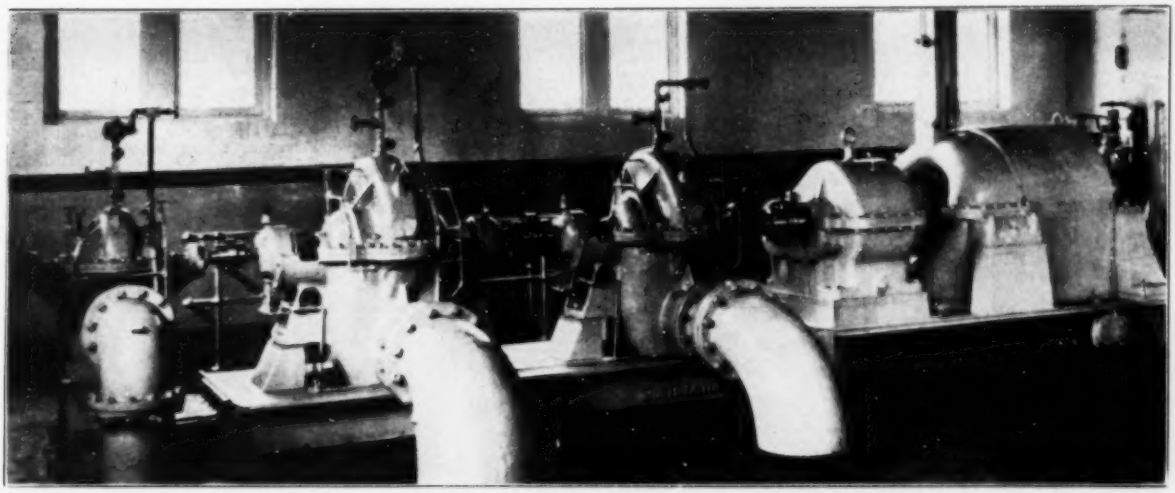


Fig. 14—Turbo-driven centrifugals in series, York, Pa., Water Co. To the left, driven through the main pump shaft, is the condenser circulating pump.

turbo-centrifugal pumping units, these lists make no comments as to information needed in order to facilitate driver selections. Obviously if these units are to be purchased with the pumps, full information as to the type to be furnished should be included in the inquiry.

Water Works Services

Raw Water (source to treatment plant)

A.—Operating head range, preferably indicated in form of system head curves for minimum, normal and maximum static heads, supplemented by information as to the duration or importance of minimum and maximum head pumpage.

B.—Capacity rating at design head.

When local conditions require obtaining certain variations in capacities with variation in total head, it is advisable, before issuing a formal inquiry, to determine from one or more pump manufacturers whether or not the desired characteristics can be obtained with constant speed. If not, it may be necessary to use a variable speed drive.

With centrifugal pumps, guarantees are ordinarily limited to one head-capacity condition. There are a few exceptions, such as large capacity, specially built units. Even in such cases the manufacturers expect a reasonable tolerance on head or capacity for any secondary guarantee point.

C.—Suction conditions, with detailed information as to how these are interrelated with total head or capacity.

D.—Character of water relative to dissolved air or gases and foreign material such as grit, leaves, etc., also chemical contamination, if any.

E.—Type of installation—horizontal or vertical with full data on local conditions.

Treated Water

(1) *Direct service into mains*

A.—Rated capacity at design head with data on operating range of capacity either alone or in parallel with other units. If the new unit or units are to operate in parallel with existing units, give characteristics of these existing units.

B.—Rated head.

C.—Suction conditions.

D.—Type of installation—i.e., horizontal or vertical.

(2) *Direct service into mains with stand pipe or reservoir on the line.*

A.—Capacity at design head with information as to desired capacity at other heads if head varies with rate of pumpage or for other reasons.

B.—Rated head with data on variation in head if there will be any variation. Describe in detail.

C.—Suction conditions.

D.—Type of installation.

(3) *Long distance pumpage through pipe line to distribution system or reservoir.* Such systems necessarily involve considerable friction heads which vary with capacity. Unless pumpage is to be at a constant rate to a distribution reservoir, full data on the system should be given with information as to what is to be accomplished.

(4) *Booster services.*

Pumps for booster service may either take water from mains under nearly constant pressure and discharge it into a distribution system in which a higher pressure is needed or may take water from mains when the pressure falls below the minimum permitted and add more pressure for the area served by the pump. Without a stand pipe on the system, pumps for the first service should generally have a reasonably small head rise so excess pressure is kept to a minimum. Depending upon local conditions and the inclusion of a stand pipe those for the second type of installation may require anything between a reasonably flat and a very steep head-capacity characteristic. For pumps to be used for booster service it is therefore necessary to outline in sufficient detail what is to be accomplished if the manufacturer is to make the proper selection.

(5) *Turbo-centrifugal pumping units.*

While there are few units of this type being purchased, the turbo-centrifugal pumping unit, i.e., steam turbine, reduction gear, centrifugal pump, circulating pump, condenser and condensate pump with interconnecting piping and auxiliaries involve various items which must be individually carefully selected so they make a proper operating whole. With this type of unit the manufacturer must be given very complete information not only on the hydraulic data but on the physical location in which the unit will be installed. The data needed is summarized as follows.

A.—Rated capacity and head, also giving range of capacity and heads to be met with data on suction conditions for these ranges.

B.—Data on steam pressure and superheat with range in variation for both.

C.—Range in water temperature specifying temperature at which duty guarantees are to be made.

D.—Discharge head for condensate pump.

E.—Drawing showing space available for the unit, location of basement operating floor, source of suction supply or location of suction main and point to which discharge is to be connected.

Sewage Services

A.—Operating head range; or, whenever two or more pumps are involved, preferably a curve showing the system head-capacity characteristics. When specifying an operating head range, be sure to take into account the reduction in friction head losses with decreased capacity resulting from an increased static head and the reverse with increased capacity resulting from a decreased static head.

B.—Capacity at average or design head with limitations, if any, at other heads. Do not make unnecessary restrictions of capacities at other than design heads. To meet these may necessitate special designs with resultant unnecessary high cost.

C.—Suction conditions, with full information on how they vary with total head, capacity or number of units in service.

D.—Type of pump installation, i.e., horizontal or vertical. If vertical, and in dry pit with shafting between the pump and motor or gear, advise elevation of pump pit floor, center line of suction (if fixed by existing construction) and motor supporting floor. If the vertical distance is such that steady bearings may be required for the vertical shafting, advise location of bearing supporting beams or of floors, if fixed by some local conditions. For vertical wet pit pumps, advise the distance from the supporting floor to the bottom of the pit. This, with information as to water levels in the pit, will permit the manufacturer to select proper length of pump shafting.

E.—Size of solids.

The maximum size of solids to be expected in straight domestic sewage is 2.5 inches diameter, as could be flushed down a water

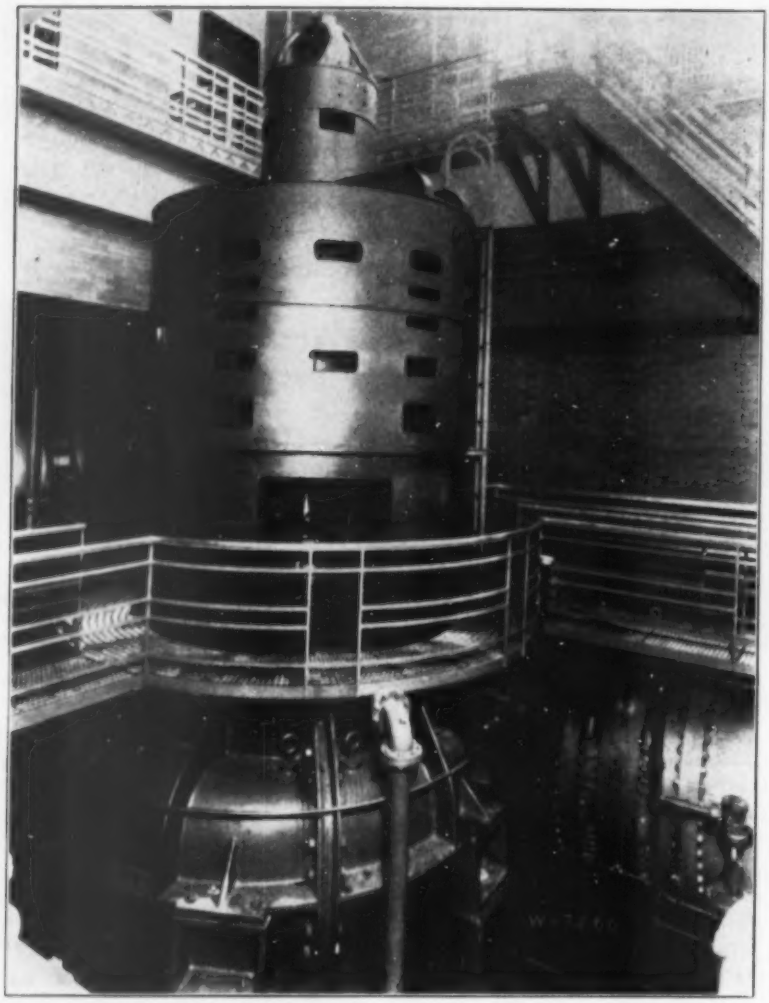


Fig. 15—Bottom-suction vertical pump, such as is used in large capacity water and sewage plants. The motor is commonly located some distance above the pump.

closet. Unless the sewage is screened or comminuted it is therefore desirable that sewage pumps on straight domestic sewage service be capable of passing 2.5 inch solids. On storm water or combined domestic and storm water systems, larger solids can be expected. It is usual practice to protect the pumps from solids larger than can pass through the bar screen ahead of the pumps. Demanding a pump design passing very large solids for the capacity involved is not desirable as it often necessitates manufacturers offering larger, more expensive and less efficient pumps than if a more reasonable smaller size solid limitation is specified.

Drainage and Irrigation

In general the specific information required for drainage and irrigation installations is the same as for sewage installations.

Boiler Feed Service

A.—Required capacity in gallons per minute or in pounds per hour, including maximum, minimum and normal. If expressed in gallons per minute, the conversion from pounds per hour should include specific gravity corrections. The total pump capacity installed, exclusive of spare equipment, should exceed the maximum steaming capacity of the boilers by 10 to 20%. This margin is intended to provide against boiler swings as well as against the eventual reduction of pump capacity through wear before renewal of internal parts take place.

B.—Temperature of the feedwater and possible variations.

C.—Suction conditions, including variations in suction pressure and information on the minimum available net positive suction head. If the pump takes its suction from a direct contact feedwater heater, the net positive suctionhead (available energy over and above the vapor pressure) is the static submergence between the water level in the storage space and the pump centerline, less the friction losses in the suction piping. If, on the other hand, the pump takes its suction from the discharge of some other pump such as the condensate or a booster pump, with closed heaters located between them, the available NPSH is the difference between the suction pressure and the vapor pressure at pumping temperature, converted into feet of water at the pumping temperature.

D.—Discharge pressure preferably, but if not available, boiler pressure, since this will permit an estimate of the required discharge pressure. From past experience, it may be said that the required discharge pressure will vary from 115 to 125% of the boiler pressure. For a more accurate determination, it is necessary to know the maximum drum pressure, the static elevation of the boiler drum above the pump floor, the friction losses in the discharge piping and in the closed heaters in the pump discharge and, finally, the losses in the feedwater regulator.

E.—Chemical analysis of the feedwater, if not complete, at least with reference to its pH value. Information, if available, on the past experience with boiler feed pump materials handling the same feedwater.

F.—Type of regulation.

G.—If possible, complete layout of the feedwater system and heat balance diagram should be supplied the pump manufacturer.

Condensate Service

A.—Capacity in gallons per minute or in pounds per hour, maximum, minimum and normal. If condensate pumps discharge through some auxiliary cooling heat exchangers such as air ejector after-condensers or oil coolers, specify the minimum flow required as this may necessitate the inclusion of automatic recirculation controls.

B.—Suction conditions, including vacuum in hotwell, minimum available submergence and expected variations.

C.—Discharge pressure: maximum, and normal. If prevailing conditions are complex, supply a system-head curve.

D.—Type of system: open or closed. In other words, does the condensate pump discharge into a direct contact heater or surge tank or does it deliver the condensate into the suction of a boiler feed pump?

E.—Type of control contemplated. Will the capacity be automatically regulated by variations in hotwell level through operation in the break, will the discharge be throttled by means of a float-regulated valve or will the float control regulate the by-passing of a certain quantity of condensate back into the condenser hotwell.

Condenser Circulation Service

A.—Rated capacity and in case of parallel operation of several or more units, desired capacity with reduced number of units in service.

B.—Rated head and in case of parallel operation of several or more units, detailed information so heads at reduced flows can be determined.

C.—Suction conditions with detailed information if conditions will result in increased capacity at reduced head operation.

D.—If pump will operate on a siphon system, will siphon be established by evacuating the entrapped air or must pump fill the siphon? If the pump must fill the siphon advise static head from suction supply to top of siphon. (Usually it is better to establish the siphon by evacuating the entrapped air.)

E.—Character of water with information as to materials of construction found suitable for existing units.

F.—Type of installation—horizontal or vertical. If latter, whether wet or dry pit with information as to local conditions.

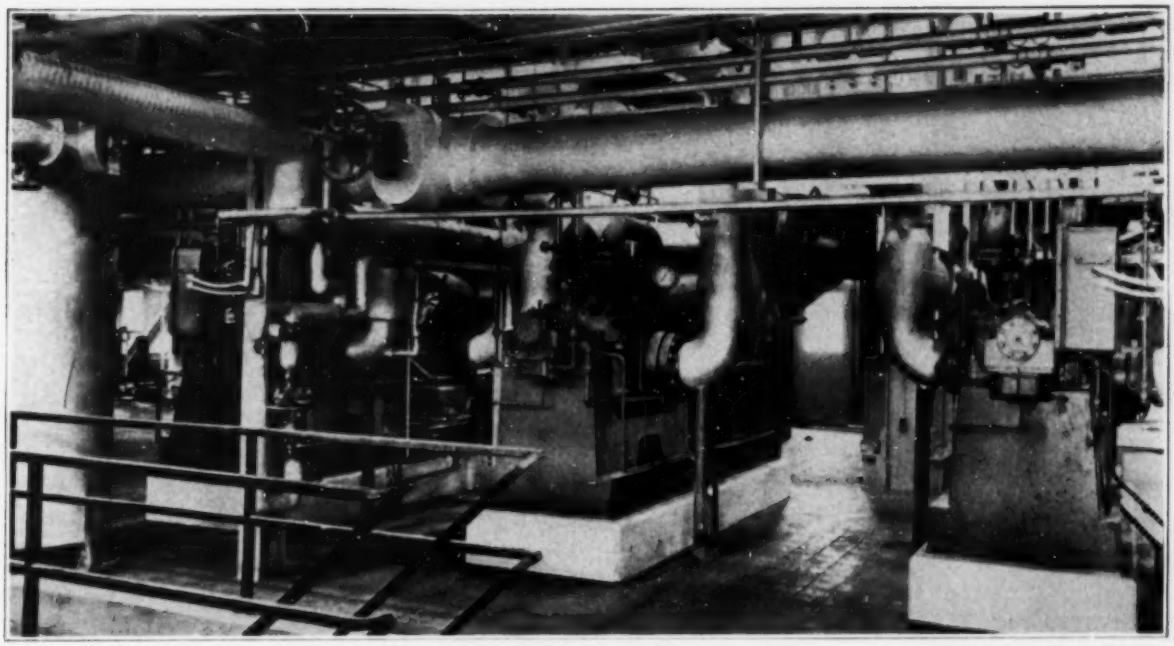


Fig. 16—Battery of high-pressure multi-stage centrifugals on boiler feed-water service. Each will deliver 850 gpm. of water at 230° F. against 1060 pounds boiler pressure.

Industrial Water Supply

The requirements for water supply to industrial plants vary widely with small to large capacities and low to very high heads handling all types of water, fresh, salt, brackish, often contaminated with chemicals. In general the data given above under "Water Works Services" and "Condenser Circulating Service" will serve as a proper guide.

Chemical Service

A.—What is the nature of the liquid? Acid or alkaline? What is the concentration of the solution? What impurities, if any, are present in the liquid to be handled? This last item is of paramount importance, as experience has shown that presence of various impurities has a marked effect on the relative resistance to corrosion of various pump materials.

B.—Does it contain solids in suspension and are they abrasive?

C.—Pumping temperature and vapor pressure or boiling point. What is the expected, or possible, variation?

D.—Specific gravity and viscosity at pumping temperature?

E.—Capacity—maximum, minimum and normal.

F.—Discharge conditions.

G.—Suction conditions. What is method used to prime pump if there is a suction lift? Can change in pump location be made (1) to arrange for operation under submergence if suction lift impractical or (2) to reduce positive suction head if sealing the stuffing box impractical?

H.—Special stuffing box requirements such as local practice with respect to packing, sealing methods, effect of dilution by sealing fluids, etc.

I.—What is past experience with various materials or combination of materials handling this liquid? In many cases, dissimilar materials of the reservoir from which the liquid is drawn and of the pump itself set up a galvanic action which may be harmful to one or the other material. In such cases, proper isolating precautions may be necessary.

Petroleum Services

(1)—*General and Cold Oil*

A.—Nature and complete description of liquid to be handled, including specific gravity over the range of pumping temperatures.

B.—Capacity—maximum, minimum and normal.

C.—Suction conditions with special consideration to Net Positive Suction Head (NPSH).

D.—Discharge conditions.

E.—Viscosity and variations if any.

F.—Corrosive and abrasive properties of liquid.

G.—Type of service relative to pump control.

(2)—*Hot Oil*

A to G as above and, in addition:

H.—Range of pumping temperatures.

I.—Vapor pressure at pumping temperature.

J.—Correction of capacity on hot to cold operating range and resulting effect on power consumption with reference to possible driver overload.

K.—Special stuffing box requirements such as local practice with respect to mechanical seals, pressure-sealing arrangements, smothering glands, etc.

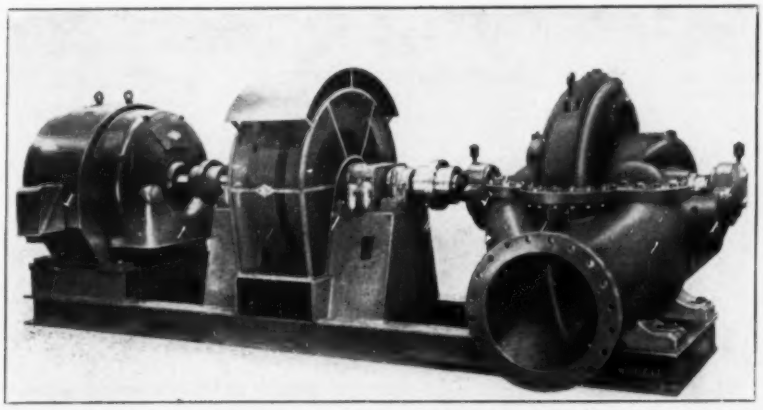


Fig. 17—Variable speed magnetic-drive unit between centrifugal pump and motor provides pump output on a sliding scale.

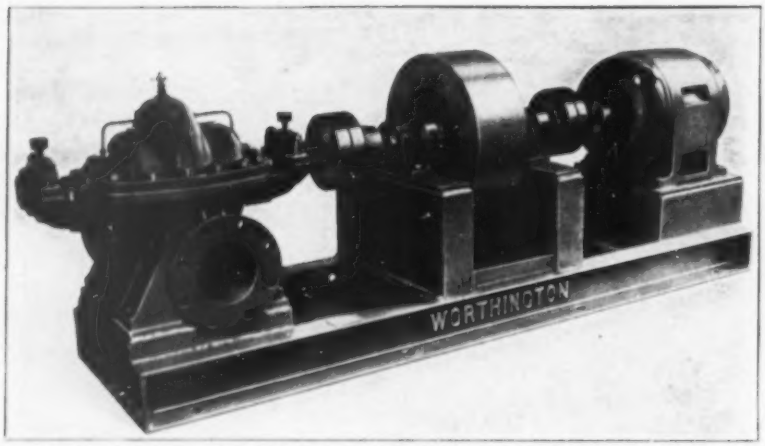


Fig. 18—Pumping unit with flywheel to keep pump operating for short interval after power is shut off. Purpose is that of moderating water hammer in case of power failure.

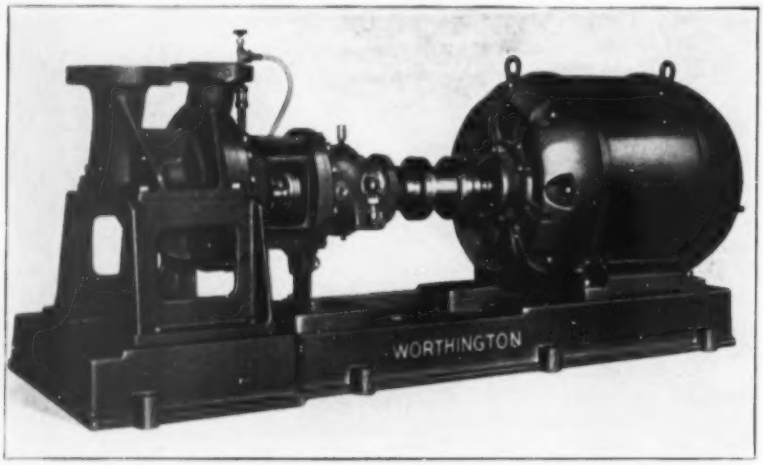


Fig. 19—A top-suction centrifugal employed in severe suction conditions, used principally in industrial processes.

(3)—*Volatile Fractions*

(Ethanes, Propanes, Butanes, Gasolines, Kerosenes, and other light fractions.)

A to G as in (1) and, in addition:

H.—Range of pumping temperatures.

I.—Vapor pressure at pumping temperatures.

J.—Special stuffing box requirements (see above).

K.—Local practice with reference to protection against fire hazards (firewalls, special driver enclosures, etc.)

(4)—*Pipeline Service*

to G as in (1) and, in addition:

H.—Graphical representation of required pressure gradients for entire pipeline.

I.—Possible variations in capacity or in nature of products handled.

J.—Method of operation: manual or automatic control.

K.—Special stuffing box requirements (see above).

L.—Local practice with reference to fire hazard.

M.—Local preference for series or single or multiple units.

Process and Paper Pulp Service

(Sugar, brine, brewery, food, paper stock, etc.)

A.—What is the nature of the liquid?

B.—Is it acid or alkaline?

C.—Is it clear or does it carry solids in suspension? Are these solids carried by floating or through agitation and flow? Are the solids inert or are they subject to dewatering or swelling? What is the consistency? What is the past experience in pumping this liquid with reference to the preceding questions?

D.—Pumping temperatures.

E.—Specific gravity and viscosity at pumping temperature.

F.—Capacity—maximum, minimum, and normal.

G.—Discharge conditions.

H.—Suction conditions.

I.—Are there any sanitary precautions to be observed? Any local preferences for specific details or materials of construction?

Mining Service

A.—Nature of mine water: chemical analysis, presence or absence of suspended materials, abrasive quality of the solids in suspension.

B.—Capacity requirements.

C.—Discharge pressure subdivided into static head and friction losses.

D.—Suction conditions.

E.—Location of installation: is space occupied an important factor? What are the size limitations imposed by transportation through the mine shaft?

F.—What special considerations need be given to the drivers? Is special insulation or enclosure necessary for the electric motors?

G.—What is previous experience with centrifugal pumps handling this mine water? What materials stood up best, which ones proved unsuitable?

Hydraulic Pressure Service

A.—Liquid used—water or oil?

B.—Capacity—maximum, minimum and normal. What is the rate of capacity change? Rapid fluctuations may require special precautions.

C.—Total head conditions (static head, friction losses, pressures to be maintained).

D.—Suction conditions.

E.—Type of pressure system. Does pump discharge directly to press or nozzles or does it discharge through an accumulator. A sketch of the installation is very helpful.

F.—Type of control. If an accumulator is used does it maintain a constant pressure automatically and is the pump shut down during the no-load operation or is it operated at no flow. If the latter, what arrangements are used for protecting the pump against overheating i.e., what controls the by-pass recirculation?

MEASUREMENT OF WATER BY CIRCULAR ORIFICE AT END OF DISCHARGE PIPE

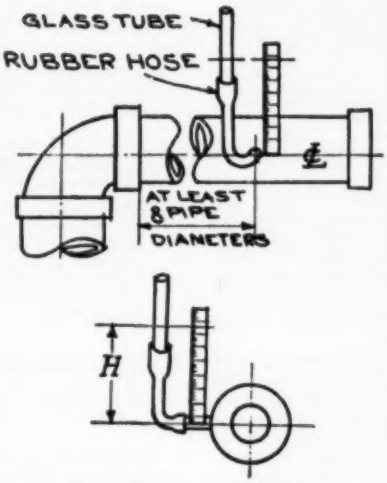
THE measurement of water flowing thru pipe lines by means of a circular orifice has been proven quite accurate, and experiments have demonstrated that a thin plate circular orifice installed at the end of a pipe line gives a rapid and accurate method for measuring such flows; the instruments being light and easily attached, permits of a simple method of testing pumping plants more accurately than the average weir that can be constructed in the field.

It is necessary that the pipe line be horizontal with no elbows, obstructions, or bends within 8 pipe diameters of discharge; the head should be measured from the center of the pipe at a point one foot or more back from the orifice.

The accompanying curve gives the discharge for 13 inch orifice on 15¼" inside diameter pipe, the formula being:

$G = KA\sqrt{2gh}$

Where G = Gallons per minute
A = Area of orifice in square inches



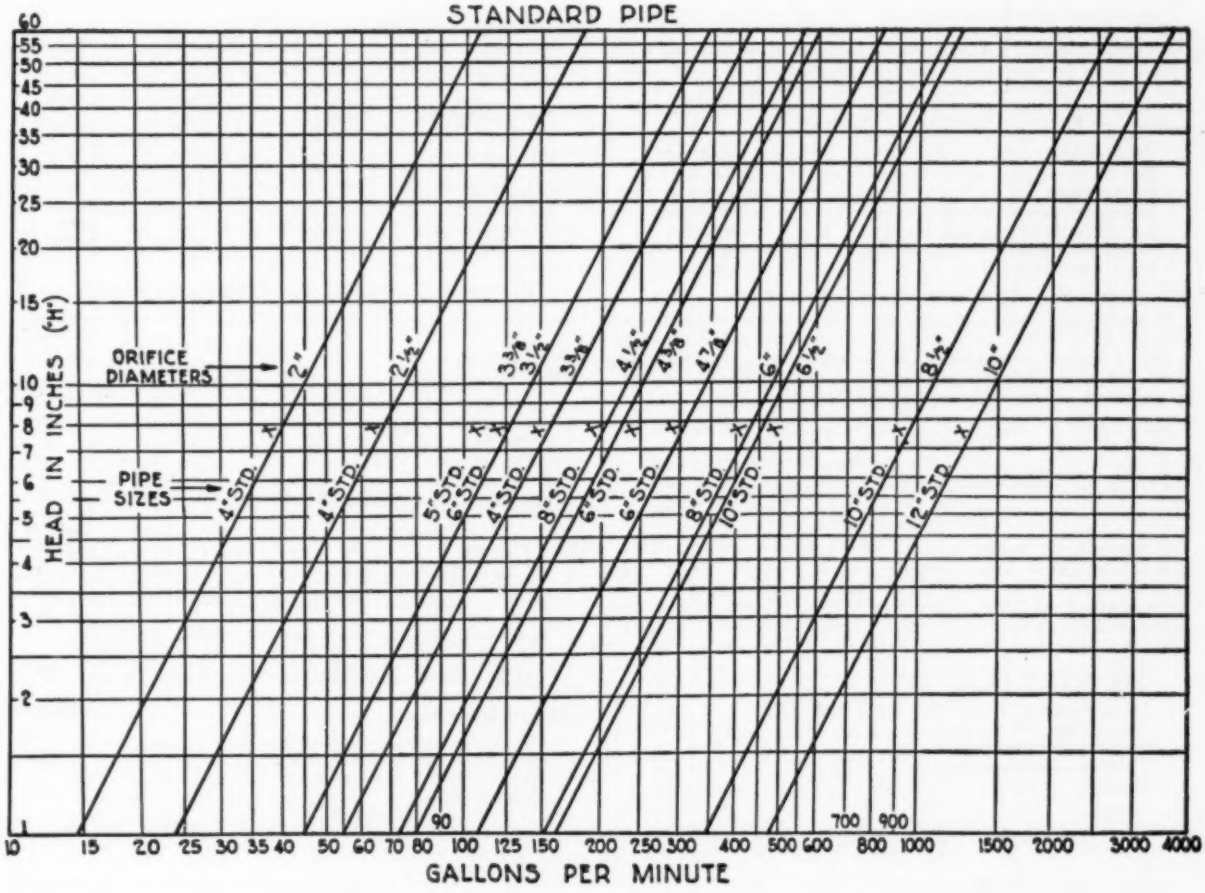
From *Peerless Pump Bulletin*

K = Constant depending on size of pipe and size of orifice.
H = Head in inches above center of discharge.

In calibrating these orifices a well constructed weir was used and the maximum variation of "K" was less than 3%. An average "K" was then taken from which these curves were constructed.

It is necessary that the orifice be running full of water and that "H" be at least one inch above top of the pipe for accurate results.

The head is measured by drilling and tapping for ⅛ in. pipe connection on the side of the discharge pipe one foot or more back of orifice, the hose connection installed and the height measured with an ordinary rule; the hole can then be plugged with an ⅛ in. pipe plug. It is very important that the ⅛ in. nipple does not extend inside the inner wall of the pipe and should be absolutely flush.



WATER REQUIREMENTS*

Volume Demand and Rates of Flow for Various Uses and Fixtures

Twenty gallons per capita daily is generally conceded to be the absolute minimum quantity of water needed to carry out, properly, the various functions of life of those served a supply of water piped into the property.

The basis for such a per user estimate is the following:

Drinking	1 gal.
Laundry	6 "
Bathing	5 "
Toilet (2 flushes)	5 "

(Possibly the item "Drinking" includes all water used in the kitchen. However, nothing is shown for scrubbing and other miscellaneous uses. So it is apparent that the average per user requirement should be at least 25 gallons and the *reasonable* minimum probably more nearly 30 gallons. In fact, surveys have revealed such to be the case.)

In an A.W.W.A. review of water consumption data the following procedure in estimating appears.*

"For purposes of estimating the probable use of water in a given building the engineer considers those quantities which are used for specific domestic operations and which do not vary appreciably with size of family, as well as the basic consumption rate of 20 gallons per capita per day. The total amount of water used in sprinkling a lawn does not vary with the number of persons living in a given house, nor does the quantity used for washing the family car. On the other hand, the use of water for personal bathing is directly related to the number of persons in the household.

"The figures which are presented here are subject to some variation but they may well serve as an index of the amounts which may reasonably be considered to be used in carrying out various domestic operations. Studies here and abroad have indicated that about one-half to two-thirds of the water used in ordinary household consumption is heated (bathing, laundering, dishwashing, etc.)."

Operation	*Quantity-of-Water*
Tub bath	25 gallons/bath
Shower bath	5 gallons/min.
Additional toilet flush/person	6 gallons/diem
Sprinkling lawn (⅝-inch hose)	7 gallons/min.
Washing automobile	150 gallons
Basic quantity/person	20 gallons/diem

"Two examples will illustrate the use of these data.

Example 1.—A family of five persons is to build a single house on a lot 50 by 100 ft. in a fairly good neighborhood. They plan to have a bathtub and do home laundering, but they have no automobile. How much water per capita (in round numbers) should be estimated as the daily consumption for this family

Basic figure $= 5 \times 20 =$	100 g.p.d.
Lawn watering = 20 min./diem for 3 mos. = 5 min./diem =	35 g.p.d.
Bathing—2 baths/week/person $= 5 \times 50/7 =$	35 g.p.d.
Total =	170 g.p.d.
Per capita consumption =	34 g.p.d.

Example 2.—A family of three is to build a large house on a plot 125 by 250 ft. in an exclusive section of town. Laundering is to be done at home and the two cars probably will be washed twice a month at home. There is a shower for the head of the house, and two baths for the two women. What water consumption per capita could be estimated here?

Basic figure $= 3 \times 20 =$	60 g.p.d.
Additional toilet flushes, $3 \times 6 =$	18 g.p.d.
Lawn watering 1 hour/day for 4 mos. = 20 mins./day for the year =	140 g.p.d.
Bathing—2 baths/day =	50 g.p.d.
Showers—10 min./diem =	50 g.p.d.
Washing cars—600 gal./mo. =	20 g.p.d.
Total	326 g.p.d.
Per capita consumption	109 g.p.d.

Similar methods of approach may be used in solving problems involving large apartments and housing projects."—Jour. A.W.W.A.

In an analysis of available survey statistics from representative cities, essentially, the following conclusions appear in the same article.*

(1) The minimum domestic water requirements for an urban community or household should be assumed at not less than 30 gals./capita/day.

(2) For design of systems, service lines and interior piping it is safer practice in general to use a figure of 40 gals./capita/day.

(3) The increase in consumption can be estimated at a rate of 1% per year, until a maximum of 50 gals./capita/day is reached.

Water Requirements in Various Types of Housing

The following estimates of expected consumption in various types of housing are based on data presented in the same review.

Type of Housing	*Gal./Capita/Day*
Single Family Houses	
Minimum	35
Reasonable	55
Maximum	100+
2, 3 and 4 Family Houses	
Minimum	35
Average	40
Maximum	55
Apartment Houses	
Average	75
Maximum	100+
Housing Projects	
Minimum	35
Reasonable	45**
Maximum	90

RATES OF DRAFT PER FIXTURE OR USE

Individual Needs	Gallons per Day
For all household purposes, including kitchen, laundry, bath, etc.	30
Each cow	10
Each horse	10
Each hog	5
Each sheep	5
Continuous flowing drinking fountains	75

Lawn Fixtures	Gallons per Hour
½-inch hose with nozzle	200
¾-inch hose with nozzle	300
Lawn sprinkler	120
Park or golf course sprinkler covering a 106-ft. diameter area, with ¼-inch main nozzle operating at 50 lbs. nozzle pressure	990

Domestic Fixtures	Gallons
Filling the ordinary lavatory	1½
Filling the average bath tub	30
Flushing water cabinet closet	6
Shower bath	30

(*From, Peerless Pump Bulletin*)

*Based on data and computations in a review of water requirements in "Domestic Water Consumption" Jour. A.W.W.A., December, 1939—by M. A. Pond, and published information from various other sources.

**In measuring the proportion of total consumption that was used as heated water the average was 66%, or 28 gallons in the average total of 42 gallons used per head.

RATES OF FLOW FROM FIXTURES

Fixture	Gallons per Minute† Fair	Good	Excellent
Bath Tubs	5	8	10
Showers (5" to 8" heads)	3	6	8
Lavatory Basins	3	5	8
Laundry Tubs	4	8	10
Sinks (Kitchen & Pantry)	4	8	10
Hose (Sprinkling & Washing)	5	8	10
Toilet Flush (Tank)	2	3	5
Toilet Flush (Flushometer)	20	30	40

†Copper and Brass Research Association figures, supported by other data.

Expected Consumption Rates and Requisite Pipe Sizes in Apartment Buildings

The following tables taken from a bulletin of the Bridgeport Brass Co. indicate expected reasonable rates of draft by apartments of various sizes and number of baths. Also is listed the minimum sizes of service lines and recommended sizes of riser pipes, based on a pressure loss of 10 lbs./100 ft. of run, and terminal fixtures pressure of 15 lbs./sq./in. during water use in all apartments on the same riser, from top floor to ground.

TABLE 1.
RATES OF USE AND DIAMETER OF WATER SUPPLY RISERS FOR APARTMENT HOUSES
(Based Upon 1-2 & 3 Baths per Ap't.)

One (1) Bath Apartment		Two (2) Bath Apartment		Three (3) Bath Apartment	
1 bath	15 gals.	2 baths	24 gals.	3 baths	30 gals.
1 W. C.	8 gals.	2 W. C.	14 gals.	3 W. C.	18 gals.
1 sink	4 gals.	1 sink	4 gals.	1 sink	4 gals.
1 lav.	4 gals.	2 lavs.	6 gals.	3 lavs.	9 gals.
	31 gals.		48 gals.		61 gals.
80% demand, 12 gals. per min.		40%, 20 gals. per min.		40%, 24 gals. per min.	

		RISER		RISER		RISER
Top Floor	15 gals.	1¼"	30 gals.	1¼"	24 gals.	1¼"
Next	28 gals.	1¼"	38 gals.	1½"	43 gals.	2"
Next	38 gals.	1½"	64 gals.	2"	64 gals.	2"
Next	51 gals.	2"	68 gals.	2"	82 gals.	2"
Next	60 gals.	2"	80 gals.	2"	96 gals.	2½"
Next	67 gals.	2"	90 gals.	2"	108 gals.	2½"
Next	71 gals.	2"	98 gals.	2½"	117 gals.	2½"
Next	78 gals.	2"	104 gals.	2½"	124 gals.	2½"
Next	81 gals.	2"	108 gals.	2½"	134 gals.	2½"
Next	83 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	84 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	85 gals.	2"	110 gals.	2½"	143 gals.	2½"

TABLE 2.
APARTMENT HOUSE SUPPLY SIZES OF SERVICE LINES FROM MAIN
(Based on Pressure Loss of 10 lbs./100 ft. Run)

For 4 and 5 Stories

No. of Baths	Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	120	2½"	160	3"	200	3"	240	3"
2 baths	160	3"	200	3"	240	3"	280	3"
3 baths	200	3"	240	3"	280	3"	320	3½"

For 6, 7 and 8 Stories

No. of Baths	Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	150	2½"	190	3"	230	3"	270	3"
2 baths	190	3"	230	3"	270	3"	310	3½"
3 bath	230	3"	270	3"	310	3½"	350	3½"

For 9, 10, 11 and 12 Stories

No. of Baths	Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	200	3"	250	3"	300	3½"	350	3½"
2 baths	250	3"	300	3½"	350	3½"	400	3½"
3 baths	300	3½"	350	3½"	400	3½"	450	4"

DELIVERY THROUGH BRASS AND COPPER PIPES OF VARIOUS SIZES FOR VARIOUS PRESSURE DROPS
(Each line being 100 ft. long)

Pressure Drop (Lbs.)	Gallons per Min. Delivery Through ⅜"	½"	¾"	1"	1½"	2"	2½"
5	2	3	7	13	40	80	150
10	3	5	10	20	60	130	225
20	4	7	15	30	90	200	300
30	5	9	20	40	120	250	375

BLOTTING OUT WASTE

Safe Water
delivered night and day
Costs Less
than anything else you buy
•• but ••
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressures without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

UNACCOUNTED-FOR WATER*

How it is Correctly Determined and Why Percentage Figures Can be Misleading

by HOMER E. BECKWITH

District Mgr., The Pitometer Co., Pittsburgh, Penna.

"UNACCOUNTED-for Water" — exactly what do we mean by this term?

To a dozen different people it can mean a dozen different things. For instance, to one man it may mean the difference between the total input to the system as shown by his master meter and the sum of the meters through which water is sold. Another may want to add to the amount of water sold items such as estimated public use, water used to fight fires, sewer flush water, estimated meter slip, etc., etc. Sometimes even the kitchen sink slips into the accounting. But it is because of this wide divergence in methods for computing "unaccounted-for water" that far too often we find that we are not talking about the same thing.

For the above reason I wish to propose a new term—"Metered Ratio." This would be defined as the percent of the total water entering the system that is shown as registration on all meters on the system—those of customers and other meters. Thus reduced to the simplest essentials, we have a term which would mean the same wherever used. When we have such a uniformity we will be able to collect data which will have meaning. I claim no patent on this idea as Wendell R. Ladue, former president of the American Water Works Association, has been preaching this gospel for some time. I am just beating the drum in the hopes of bringing in more converts to this meaningful and realistic term.

Only too often the operator starts out with a preconceived idea of what his percentage of accounted-for water should be. If he finds that his records do not produce this preconceived figure, he may juggle his items until he gets an answer that does conform with what he thinks it should be. In an exaggerated case the writer once saw an accounting which showed that, on an annual basis 3,000,000 gpd were used to fight fires out of a total pumpage of 17,000,000 gpd. Later investigation showed, of course, that this figure was wide of the mark.

So let us start off on a basis which admits of no misunderstandings. Let us assume that only the water shown on the customers' meters is accounted for—that is, the "metered ratio" and the percentage of "water accounted for" are identical. We can then study the factors which contribute to the "unmetered" or "unaccounted for" water.

When Must We Start?

To start at the beginning, we must accurately know the amount of water entering the system. This should be measured by master meters at the pumping station or filtration plant. If the filter wash water passes through the master meters and is thus recorded on them, the amount of this wash water should be carefully recorded and subtracted from the master meter readings. This filter wash water is part of the material expended to produce the plant output available for sale and is really just as much a part of the production cost of the finished water as are coal, electricity, or chemicals. The temptation to include filter wash water in the total figure for water produced in order to hold down the unit cost is understandable, but if we are to ever get figures which mean anything we must use the same basis in all instances. Since not all plants filter their supply the only true basis for arriving at comparable results from system to system is to use as the base the amount of water entering the system after all plant uses are deducted.

Having decided on a basis for determining the amount of water to be accounted for, we must next be certain that our determination of this amount is correct. At present the usual method for measuring this amount is by the use of Venturi type meters, orifice plate meters, turbine type meters, pitot tubes, etc. Any of these meters will give reliable measurements if correctly installed, checked for accuracy, and properly maintained. No meter can be installed and then forgotten. Any piece of equipment needs checking from time to time—even such a rugged piece of mechanism as a Venturi meter. Not only should the recording portion be checked but the tube as well. Anything which disturbs the area ratio between the throat and pipe at the points where the pressures are taken will cause a false reading. Incrustation growing over the throat or stones or other foreign matter working down into the throat are examples of conditions which have been found to cause false readings. For this reason, it is desirable to not only check the instrument by using the standard tests outlined in the instructions which come with the meter, but from time to time it may be well to make tests by comparative measurements, using some other instrument such as the Pitot tube.

Practical Limitations in Water Accounting

Not even in the best maintained systems is it possible to register on the consumers' meters all the water entering the system. Not even all of the water which reaches the consumer is shown on the consumer's meters. This is because meters begin to deteriorate from the time they are set and inevitably there are always some meters in the average system which are running somewhat slow—especially so on the minor flows which too frequently do not register at all. Moreover, even with new meters, it is practically impossible to catch the drip flows. The inertia of the moving parts of customers' meters is usually sufficient to permit the very small amount of water feeding dripping faucets to slip past without moving the meter. The amount from each individual drip is insignificant enough; but, taken as a whole for the entire system total lost registration from these small individual seeps is considerable, possibly as much as 5% of the total pumpage in an average system, and assuredly more where meter maintenance is neglected.

Large commercial and industrial meters often under-register the water passing through them, sometimes because the meter is worn, but often because the meter is improperly chosen as to size and type for the particular job it has to do. Or it may be improperly set. Meter manufacturers are only too glad to cooperate with their customers in selecting the proper type of meter and in securing the proper setting. It is wise to avail one's self of this help.

From what I have been told, all meters are not equally sensitive. On this subject I cannot speak with authority, but it seems natural to suppose that one gets only the quality one pays for, and one cannot expect as high a percentage of registration from meters purchased on a price basis as can be expected from meters purchased on a quality basis. The amount of flow required to start a meter operating (its sensitivity) has an appreciable effect on "accounted for" water.

The time interval between readings is also a contributing factor. Not only can meters turn over if too much time elapses, but stopped meters are not caught so soon and the amount of under-registration accordingly is increased.

Indifferent Maintenance

Only too often meters are permitted to operate until they stop completely before they are brought in for test or repair. As most meters start to under-register some time before final failure, neglect in meter maintenance is bound to contribute to the increase in the amount of "unaccounted for" water on any system where such neglect exists. A much better plan is to bring meters in systematically, say at the end of some specified period, possibly five or six years, for test and overhaul even though they may still appear to be functioning properly. Some operators prefer to base the test period upon the amount of flow registered by the meter, instead of upon the less significant elapsed time in service. There is a great deal to be said for this position, but probably the ideal set-up would be a combination of the two—*so much registration or so much time*, whichever comes first. Too much emphasis cannot be placed upon proper meter maintenance if the desirable high "metered ratio" is to be obtained. Nor should we forget that the meters are looked upon as "the cash register" (more properly the scales) of the water works industry and money is as necessary in this as in any other branch of business enterprise.

The "Free Water" Racket

Then there is the "free water" racket. Too frequently charitable institutions, churches, schools, parks, playgrounds and public buildings are given water service without charge. Perhaps the real weakness of this situation lies not so much in the fact that the water is free but that no effort is made to control its waste. It is a human trait to value lightly anything which is free. A much more realistic approach to this problem of free water is to meter all such services, so that a check is had on the amount of water used. Then, if necessary or desirable, give a reasonable amount of water as a contribution. But when the meter registration shows that the privilege is being abused, through waste or otherwise, a charge should be made for the excess registration. Nothing increases our appreciation of any article or service as much as having to pay for it.

Nor should the sewer department be permitted to turn the flow from fire hydrants

*This paper, presented before the Virginia Section of A.W.W.A., has been released for publication in *Water & Sewage Works*.

into sewers with such gay abandon. There is something about the sound of running water which is very relaxing to the human ear. The temptation to shove a fire hose down the end of a sewer and sit in the shade of a convenient tree listening to the sound of rushing water is often too great for the members of the sewer flushing crews to resist. The result is that these flows are often permitted to continue long after the sewer has been fully flushed. The use of a portable meter to measure all water used for sewer flushing should be required as a deterrent to wasteful practices. I know such meters cost money but so does the water now carelessly wasted. In the long run, the meter will prove to be the less expensive of the two.

Another occasional contributor to water losses is the unmetered fire line, and the unauthorized connection. Most people are honest but there are enough of the other kind to make it necessary to keep a watch upon all places where surreptitious connections can be made. It even happens occasionally that honest persons inadvertently make connections to unmetered lines.

Those Hidden Leaks and Seeps

Then there is another type of loss which increases the spread between the pumpage and the sales. This is the underground leak. The leak which shows upon the surface is quickly located and repaired, but the loss which occurs between the inception and the repair of the leak is a part of the "unaccounted for water" we are discussing. However, the leak which does not show on the surface and continues to waste water day after day, week after week, month after month, and even year after year, contributes an amount which is only too often underestimated. No distribution system is bottle tight. A certain amount of water is inevitably lost from small seepages at the joints. Even if the exact location of each and every one of these small leaks were known, at present day labor costs it would cost more to dig them up and repair them than to permit them to continue to exist. The amount of loss from these seeps will vary from one system to another and will depend a great deal upon the nature of the soil, type of joint, etc. The larger the average diameter of the pipe in the distribution system the higher will be the loss from this source. For cities of average size, a figure of 3,000 gallons per day per mile of main should not be far from the mark. For larger cities the figure will be a bit higher.

But in most cities there are a number of underground leaks which waste an appreciable amount of water. The location and repair of these leaks can materially reduce the amount of "unaccounted for water." The cost of locating and repairing such leaks is often only a fraction of the value of the water being wasted.

Within the memory of a great many of us here today, the typical water plant pumped water by steam power either from wells or large surface supplies directly into the distribution system without purification of any kind. Or the water may have flowed by gravity from impounding reservoirs without any pumping costs whatever. Under those circumstances it was difficult to see that water had any particular value. Even when pumped, a small increase in waste caused no measurable decrease in the amount of coal thrown under the boiler. But now things are different. Water is a manufactured product. Every gallon requires filter capacity and its quota of chemicals. Even our power units have largely changed. Electric power has replaced steam in an increasing number of plants. The result is that the cost of pumping is influenced even by small changes in the amount of water handled. Right now with output often equalling or even exceeding the rated theoretical capacity of our plants, water has a value far beyond that of the chemicals and power which are required for its production. Costs of capital equipment must also be considered. A water department which could decrease its load from 10,000,000 gpd to 9,000,000 gpd would automatically reduce its need for plant capacity by 1,000,000 gpd. If the plant requires a margin of safety, the reduction in required capacity would even exceed 1,000,000 gpd. The capital value of this saving in filter capacity, pumps, settling basins, etc., would probably be not far from $200,000.00 at present prices. This may be somewhat beside the point of this paper, but it does emphasize the fact that when we are discussing "unaccounted for water" we are also talking about important money.

Many Conditions to Evaluate in Comparing Systems

It will be readily seen from the previous discussion that many things contribute to this item of "unaccounted for" water. And not all of these factors affect all plants in the same way. Meter quality and maintenance will vary from plant to plant and underground conditions which control the amount of leakage will not be the same everywhere. Moreover, a little reflection will show that the amount of meter nonregistration on drip-rate flows will depend upon the number of meters and not upon the amount of water taken through the meters. That is, the loss will be more a factor of the number of persons served than it will be of the gallons of water consumed by those persons. The amount of water lost from seeps will depend much more upon the mileage of main (number of joints) than it will upon the amount of use from that main. An average mile of 6" main from which 5,000 gpd is taken by consumers will lose as much by seepage as a mile of 6" main from which 20,000 gpd is taken. In the first case the unaccounted for water percentage-wise will be four times that in the second case. So percentages are not too reliable an index unless applied to each particular plant based upon the history of that plant. The speaker recalls two neighboring plants where intensive efforts were made to reduce the "unaccounted for water." The final result was that one plant achieved a "metered ratio" of 88% while its neighbor only achieved a ratio of 72%. However, in the first plant the per capita use of water was 90 gallons per day and in the second plant it was 40 gallons. It will be seen that in each case the per capita loss was about 11 gpd. This was to be expected as the underground conditions were similar and the number of consumers per mile of main was about the same. The principal difference lay in the fact that one system had a large industrial load and the other had practically none.

It can be readily comprehended that what may be a very satisfactory "metered ratio" in one plant would be highly unsatisfactory in another. The only way to find out what it should be on each individual plant is to make an intensive campaign to eliminate preventable waste from all sources. When this has been done, the resulting metered ratio should be the correct one for that particular plant and should serve as a yardstick by which to measure future performance.

Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters ÷ 2.54 = inches.
Meters × 39.37 = inches (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers × 3280.8693 = feet.
Square Millimeters × .00155 = sq. inches.
Square Millimeters ÷ 645.1 = sq. inches.
Square Centimeters × .155 = sq. inches.
Square Centimeters ÷ 6.451 = sq. inches.
Square Meters × 10.764 = sq. feet.
Square Kilometers × 247.1 = acres.
Hectare × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.
Cubic Centimeters ÷ 3.69 = fl. drams (U. S. P.).
Cubic Centimeters ÷ 29.57 = fluid ounces (U.S.P.).
Cubic Meters × 35.315 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons (231. cubic inches).
Liters × 61.022 = cu. in. (Act of Congress).
Liters × 33.84 = fluid ounces (U. S. P.)
Liters × .2642 = gallons (231. cu. in.).
Liters ÷ 3.78 = gallons (231. cu. in.).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cu. in.).
Hectoliters × .131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231. cu. in.).
Grams × 15.432 = grains (Act of Congress).
Grams ÷ 981. = dynes.
Grams (water) ÷ 29.57 = fluid ounces.
Grams ÷ 28.35 = ounces avoirdupois.
Grams per Cu. Cent. ÷ 27.7 = lbs. per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = oz. avoirdupois.
Kilograms ÷ 907.2 = tons (2,000 lbs.)
Kilograms per Sq. Cent. × 14.223 = lbs. per sq. in.
Kilogram-meters × 7.233 = foot lbs.
Kilograms per Meter × .672 = lbs. per foot.
Kilograms per Cu. Meter × .062 = lbs. per cubic foot.
Tonneau × 1.1023 = tons (2,000 lbs.).
Kilowatts × 1.34 = Horse Power.
Watts ÷ 746. = Horse Power.
Watts × .7373 = foot pounds per second.
Calorie × 3.968 = B.t.u.
Cheval vapeur ÷ .9863 = Horse Power.
(Centigrade × 1.8) + 32 = degrees Fahr.
Gravity Paris = 980.94 centimeters per sec.

DEWATERING MAINS WITH COMPRESSED AIR

By ARTHUR C. KING
Superintendent of Water Works, Taunton, Mass.

HERE in Taunton, Mass., we have adopted the use of compressed air for removing water from mains, developed by Esty and Boardman, and have successfully used the method on pipe of such size that we believe our experience might be of interest to others who may have questioned the value of the scheme for mains of larger sizes. (See sketches.)

An Experience with a 12-Inch Main

It became necessary to relocate about 600 feet of 12 in. cast iron main. Since occupied buildings were supplied from the section to be relocated, it was decided to lay the new main before cutting off the old for salvage.

After the new pipe was laid, the problem was that of making the connections between the old and new as quickly as possible, both on account of regular use and also the reduction in fire protection during the changeover. The section to be drained (about 2500 ft.), lay on an up-grade, as will be seen on the accompanying sketch (a), and hydrants were already in place at the high end and near the low end. The main was shut down, the hydrant near the low end was opened, and the air compressor connected to the hydrant *at the high end.* In a surprisingly short time, perhaps 40 minutes, although it was not timed, water ceased to come out of the hydrant and the main was cut. No water came out through the cut. The old and new sections were connected and the water turned into part of the new main within 4 hours, restoring service to all buildings. The upper end was then cut off and reconnected. Not a bit of ditch pumping was required.

We Try a 16-Inch Main

Another large main dewatered with compressed air was of 16 in. cast iron. The length between gates was about 1200 feet—see sketch (b). About 800 feet was on a slight up-grade to a summit, where there was a hydrant. The other 400 feet was on a downgrade to the point of cutting, with a hydrant in that shut-down section just beyond the cut. The low hydrant was opened and the compressor connected to the hydrant at the summit. The water was quickly driven out and the cut made. In this case, apparently some gate was not shut quite tight as a trickle of water occasionally came out, but it was not enough to make trouble for us. We considered this job also a remarkable demonstration of the Danvers method.

On second thought, another hydrant might have been opened to dewater part of the main on the slope back from the summit away from the work, before the cut was made. Then the leakage would have accumulated back of the summit.

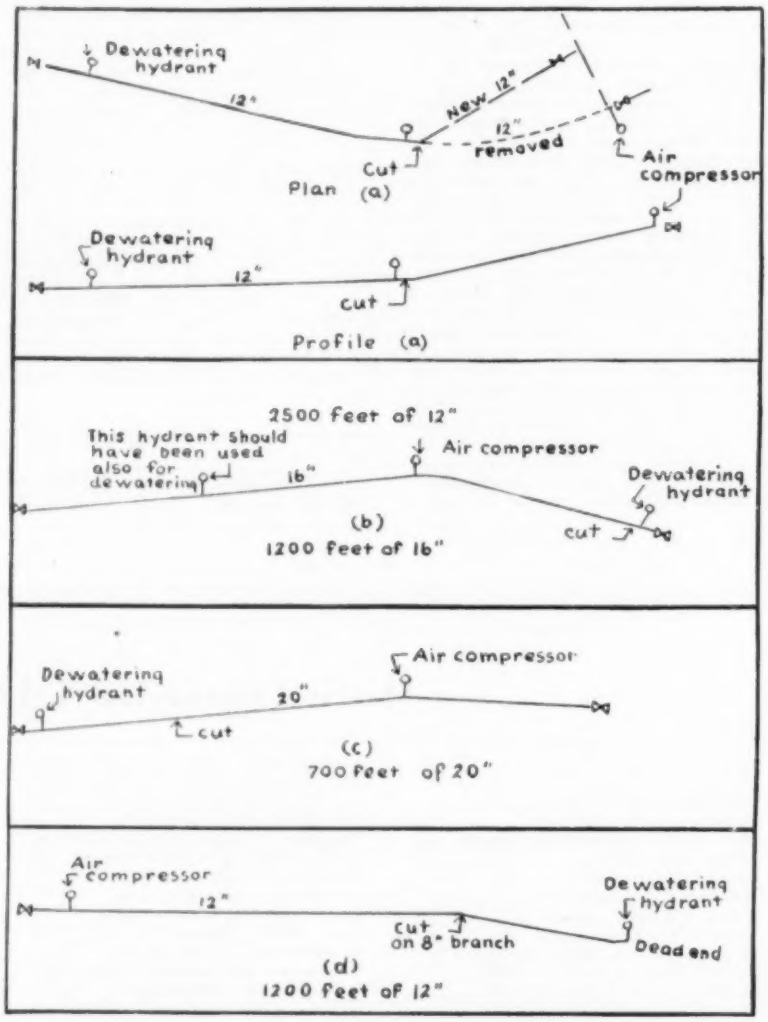
We Do a 20-inch Job

On another occasion we used the air to empty about 700 feet of 20 in. cast iron pipe, sketch (c). The upper end was nearly level for about 200 feet then the pipe sloped down from a hydrant at the summit about 500 feet past the work to be done to a hydrant at the low end. Here again no difficulty was experienced and the water was driven out very quickly, but was not timed.

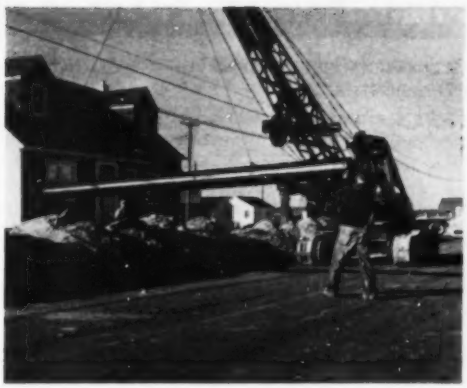
We also drained about 1200 feet of 12 in. cast iron shown on sketch (d). In this case we cut out and replaced an 8 in. gate valve on a branch main a few feet away, and on an up-grade, from the 12 in. main. The whole job of dewatering, cutting out the old and inserting the new gate was completed in less than 2 hours.

Our compressor is set for a maximum of 95 pounds pressure and starts up when the pressure drops about 10 pounds. We did not note what pressure was held during dewatering, but there was no indication of lack of air or pressure for these lengths of 12 in., 16 in., and 20 in. mains. The rated capacity of our compressor is 110 cubic feet per minute.

The scheme proved its worth very effectively.



Sketches Revealing Conditions in Main Dewatering Experiences Employing Compressed Air



Installing 10" U. S. centrifugally cast iron pipe for a water distribution system

CAST IRON PIPE FOR WATER SERVICE

The practice of using cast iron pipe for water service started in Europe around 1455 and around 1820 in this country. This practice has continued down through the years and it is still the most widely used type of pipe for water distribution systems. The most desirable combination of strength and long life has made and still makes the use of cast iron pipe the most economical in the long run. Our strategically located foundries are well equipped to furnish cast iron pipe and fittings in sizes starting at 2-inch for intakes, pump stations, filtration plants, supply, feeder and distribution mains.

CAST IRON PIPE FOR SEWERAGE SERVICE

Cast iron pipe and fittings have a wide application in the sewerage field. They have three outstanding properties: 1. tight pressure type joints that prevent infiltration, 2. beam strength, compressive strength and bursting strength to withstand severe installation conditions, 3. long life and resultant low amortization charges that have been proven by years of satisfactory service.

Cast iron pipe and fittings in sizes 2-inch and up can be furnished for flow lines, pressure mains, siphons, stream crossings, outfalls, pumping stations and treatment plants.

Section of 36" cast iron outfall sewer installed on concrete piers

TYPES OF PIPE AVAILABLE

Our cast iron pipe centrifugally cast in metal molds is manufactured in accordance with American Standard Specifications A21.6 or Federal Specification WW-P-421. Pit-cast pipe is made to conform to American Standard Specifications A21.2.

Fittings (bell-and-spigot) can be furnished in accordance with American Standard Specifications A21.10 for the short-body type 3-inch to 12-inch, also A.W.W.A. Specifications C100 3-inch to 60-inch for the long-body type.

Fittings (flanged) are made to conform to American Standard Specifications Class 125 (B16.1) and Class 250 (B16b) or long-body A.W.W.A. type.

Mechanical joint for cast iron pipe and fittings is made in accordance with American Standard Specifications A21.11. Pipe and fittings can be furnished with cement lining in accordance with American Standard Specifications A21.4 or manufacturer's standard.

Flexible joint pipe, flanged pipe and plain end pipe are made to standard or manufacturer's specifications, whichever are applicable.

U.S. cast iron PIPE

FOR WATER GAS SEWERAGE AND INDUSTRIAL SERVICE

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: Burlington, New Jersey

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CHICAGO BRIDGE & IRON COMPANY

Since 1893, Chicago Bridge & Iron Company has been designing, fabricating and erecting elevated steel tanks and many other types of steel plate work for municipal water systems throughout the country. These 60 years have been years of progress. They have given us a vast background of experience which has led to structural improvements, better workmanship and efficient erection methods. Tank designs have been constantly improved to provide today's pleasing, streamlined structures.

Tanks for municipal service are built by Chicago Bridge and Iron Company in accordance with specifications of the American Water Works Association. Four strategically located plants in Birmingham, Chicago, Salt Lake City and Greenville, Pennsylvania are always ready to serve you.

ELEVATED WATER TANKS

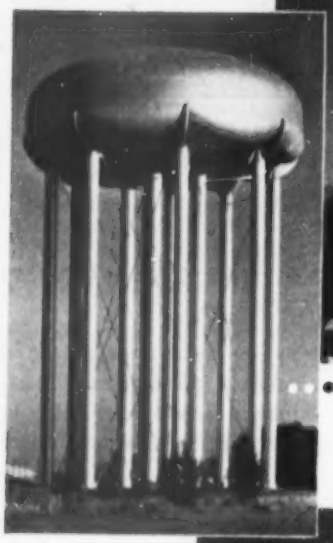
Horton elevated water tanks are designed to provide dependable gravity pressure in water distribution systems. They usually reduce pressure variations in the mains and often cut down pumping costs.

Horton elevated water tanks are built in four basic types—ellipsoidal-bottom tanks, radial-cone bottom tanks, Waterspheres and Hortonspheroidal tanks. We shall be pleased to submit estimating figures or quotations on any of them. When writing please state capacity, height to bottom, range in head, location and shape or design desired. There is no obligation on your part.

WATERSPHERES

The smooth, streamlined Watersphere presents a pleasing appearance. All piping connections and ladders are located inside the supporting column to which access is provided by a door at ground level. The lower portion of the supporting column may also be used as a pumphouse.

CAPACITY IN GALLONS	DIAMETER OF SPHERE
25,000	19'4"
30,000	20'4"
40,000	22'4"
50,000	24'0"
60,000	25'6"
75,000	27'4"
100,000	30'0"
150,000	34'0"
200,000	37'6"
250,000	40'6"



ELLIPSOIDAL-BOTTOM WATER TANKS

Ellipsoidal-bottom elevated tanks are relatively large diameter and shallow depth. Unless otherwise specified, they are built with cylindrical columns and ellipsoidal roofs.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
50,000	22'0"	19'0"
60,000	24'0"	19'0"
75,000	26'0"	21'0"
100,000	28'0"	24'0"
125,000	30'0"	25'5"
150,000	32'0"	27'6"
200,000	36'0"	29'6"
250,000	40'0"	29'0"
300,000	43'0"	30'0"
400,000	46'0"	35'0"
500,000	50'0"	37'6"

HORTONSPHEROIDAL WATER TANKS

Hortonspheroidal elevated tanks are modern, attractive structures. They are built in standard capacities of 1,000,000 to 3,000,000 gallons and are supported either on two rings of cylindrical columns or one ring of cylindrical columns and a large central riser.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
1,000,000	87'6"	25'
1,000,000	81'0"	30'
1,500,000	92'0"	35'
2,000,000	106'0"	35'
2,500,000	117'0"	35'
3,000,000	120'0"	40'

RADIAL-CONE BOTTOM WATER TANKS

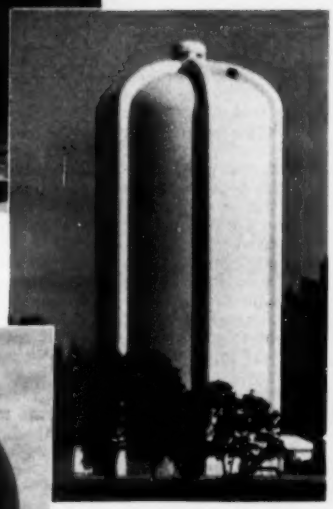
A functional design that permits large capacity water tanks to be built with a relatively low range in head. They are pleasing in appearance and easy to maintain.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
500,000	60'4"	25'
750,000	74'3"	25'
750,000	67'6"	30'
1,000,000	86'0"	25'
1,000,000	78'0"	30'
1,000,000	71'6"	35'
1,500,000	104'0"	25'
1,500,000	96'0"	30'
1,500,000	88'0"	35'
2,000,000	112'0"	30'
2,000,000	102'0"	35'
2,500,000	114'0"	35'
3,000,000	117'0"	40'

CHICAGO BRIDGE & IRON COMPANY

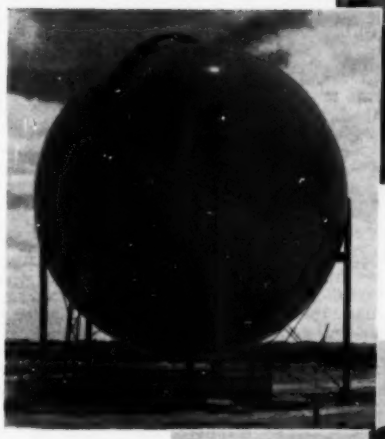
WELDED STEEL RESERVOIRS . . . . . .

Chicago Bridge & Iron Company builds welded steel reservoirs and standpipes in standard capacities up to 10,000,000 gallons. Also in special designs similar to those shown in the views at the right. Our careful fabrication and erection methods assure a long service life. Welded construction resulting in smooth tank surfaces makes painting and maintenance easy and less costly.



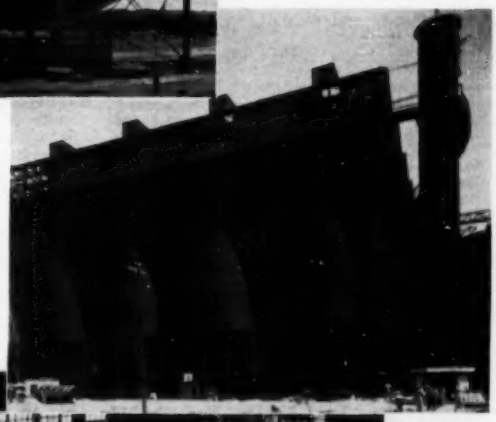
HORTONSPHERES FOR DIGESTER GAS . . . . .

Hortonspheres provide an economical means of storing sewage plant gas under pressure, and thus permit the gas produced in digesters to be utilized effectively. When the *supply* of digester gas exceeds demand, the surplus is pumped into the Hortonsphere. When the *demand* exceeds the supply, gas flows from the Hortonsphere to make up the difference. The entire shell of the Hortonsphere is accessible for inspection and painting. Hortonspheres are built in capacities up to 1,500,000 cu. ft.



STEEL PLATE WORK . . . . . .

Our design, fabrication and erection departments have had years of experience in supplying water and sewage plants throughout the country with all types of heavy steel plate work. When requesting quotations on steel plate work, please send plans and specifications if they are available.



PHOSPHORIC ACID PROCESS PICKLING AND PAINTING. . .

The Horton phosphoric acid process of pickling and painting fabricated steel plates will save maintenance dollars and prolong the life of steel plate structures. This process removes mill scale and deposits a thin coat of iron phosphate on the surface of the metal which provides a better bond between the prime coat of paint and the steel.

PLANTS — Birmingham, Chicago, Salt Lake City, and Greenville, Pa.

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Los Angeles 17 1508 Gen. Petroleum Bldg.
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Tulsa 3 ..... 1641 Hunt Bldg.

In Canada: HORTON STEEL WORKS, LIMITED, FORT ERIE, ONTARIO

REPAINTING STEEL WATER TANKS*

By J. O. JACKSON,**

Vice Pres. in Charge of Engineering & Research,
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CORROSION prevention is unquestionably the most important item in steel water tank maintenance. While other methods of corrosion control such as cathodic protection and metallic coatings are effective in many instances, paint remains the most important method of preventing or reducing corrosion in steel water tanks. This article outlines the best known methods of surface preparation and suggests several paint systems which have been found to be most dependable and effective in general use.

The painting of steel water tanks involves several types of surfaces: the interior water immersed surfaces, the surfaces above the maximum water level, and the surfaces alternately wet and dry, the exterior or weather exposed surfaces, and the underside of flat tank bottoms which are inaccessible after the tank is completed. The underside of steel tank bottoms on concrete or clean gravel undergoes very little corrosion and seldom requires more than occasional reflashing around the outside circumference.

Outside Surfaces

The outside surfaces of steel water tanks are exposed to the weather, the nature of which varies from a corrosive industrial atmosphere, a non-corrosive rural atmosphere, desert heat and dry climates, tropical humidity and rainfall, and salt air or sea coast locations.

Paint is almost always used to protect outside surfaces although there have been cases of sprayed metal protection and hot applied coating used in acute corrosive conditions such as in chemical plants and sea coast locations.

Inside Surfaces

The interiors of steel water tanks have been protected from corrosion in a number of ways. These include cathodic protection, metallic coatings, wax or grease coatings, hot coatings and linings, cement linings, and paints. The life of all interior protection is affected to some degree by the chemical nature of the stored water. This varies considerably in different localities. Instances are known where a certain paint which gives good wood protection in one locality is entirely removed from the inside surface of a tank within a few weeks in another locality. Owners of steel water tanks must therefore determine the best method of protecting the inside surfaces of their tanks to suit the chemical nature of their water.

If no suitable materials of reasonable cost are known to be satisfactory for a given water, it is suggested that a test be made by dividing the interior of a tank into sections and painting with several types of paints and placed in service. Periodic inspections will soon divulge the best paint for any condition. For further information on conducting tests, including suggested paints, see article entitled "Experimental Studies of Tank Coating Materials," *Jour. of Amer. Water Works Assn.*, Sept. 1941.

CATHODIC PROTECTION has been found to be quite effective in moderate climates but is not recommended for cold climates where ice may damage the electrodes. Where cathodic protection is used, the intermittently wetted surfaces and the surfaces above the high water level should be painted.

SPRAYED METALLIC COATINGS are very effective with corrosive waters. They are usually covered with a plastic paint or coating to reduce the inherent porosity of the sprayed metal. Zinc is most effective because of its sacrificial protection of the tank steel and because of its proximity to iron in the electromotive series. The cost of sprayed metal coatings properly protected is much more than for most paints.

WAX OR GREASE COATINGS are often very effective in interior tank protection. If the water is clean and there is no violent agitation of the tank contents, this material should be considered. Instances are known where the interiors of tanks have been adequately protected for more than fifteen years with a single application of a heavy grease coating. There have also been instances of unsatisfactory service with materials of this type.

HOT COATINGS include materials which are applied hot and which harden on cooling to a more or less plastic condition. Among these are coal tar, natural asphalt, and synthetic plastics and linings. Many of these are excellent coatings for water tank insides. Some are quite expensive both as to the cost of materials and application. They deserve consideration in cases where less costly paints are unsuitable.

CEMENT LININGS may be either portland or other cements or mixtures. They have been successfully used in many localities where other materials have given trouble.

PAINTS are the most generally used protective material for water tank insides. If the surface is properly prepared and a

*A "Guide for Tank Maintenance Inspection," by Mr. Jackson, appears in the Reference and Data Section of this issue.

**Member A.W.W.A., Committee on Elevated Steel Water Tanks, Standpipes and Reservoirs. Chairman, Research and Publications Committee, Steel Structures Painting Council.

Fig. 1.—Interior of Tank: Left, Uncleaned Corroded Paint—Right, Sand Blasted and Painted

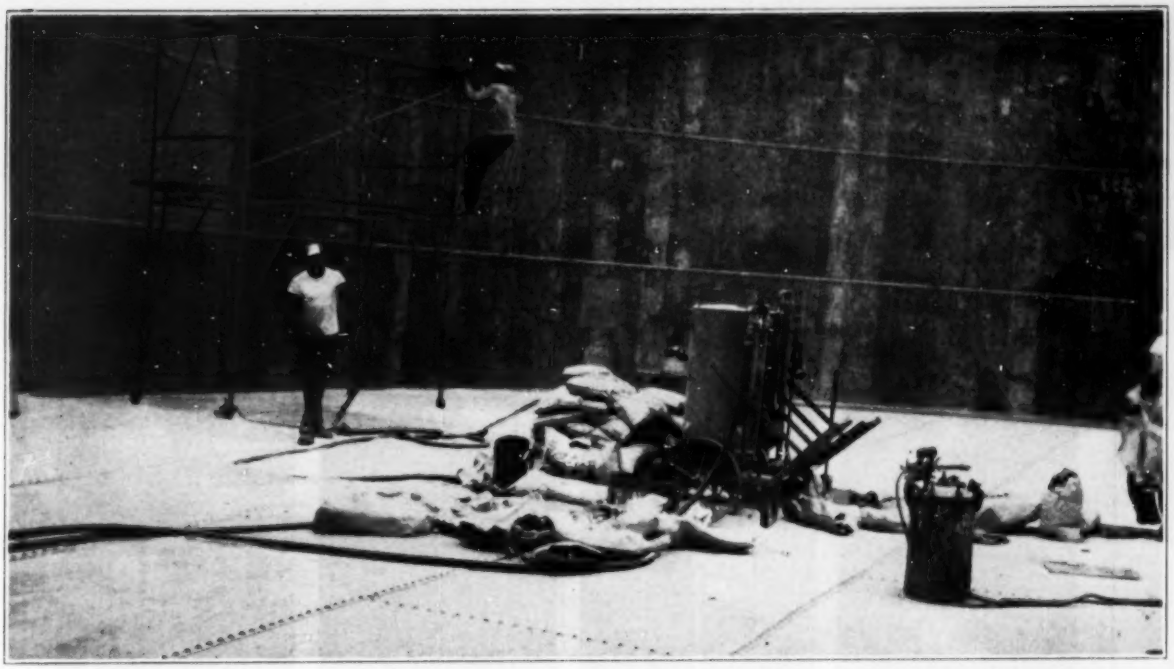


Fig. 2.—Open Top Tank Being Blast Cleaned—Blast Machine is in Center—Blast Cleaned Area at Left—Dolly on Casters Provides Scaffold at Convenient Levels and Is Easily Moved

suitable paint formulation is used, satisfactory and economical protection can be obtained in most localities. Because paint is the generally preferred method and because in some cases unsuitable paints and faulty surface preparation methods have been used, there is included hereafter a detailed discussion of surface preparation and a number of recommended paint systems which have been found to give excellent protection with most types of water.

The secret of successful and economical paint protection is:

1. Proper Surface Preparation.
2. Suitable Paint Materials.
3. Proper Application to Required Thickness.
4. Proper Maintenance of the Paint Film by Annual Inspection and Repair.

Surface Preparation

Paint applied over dirt, rust, loose mill scale or blisters cannot give satisfactory protection. If the old paint is in good condition it will be so hard and tight that it will be difficult to remove, and if it is clean and not too thick it will be satisfactory to leave in place. Cleaning may be done by hand or power wire brushing, hand scrapers, sand or emery paper, or by blasting.

The best method to use will depend upon the surface to be cleaned and the amount to be done. For field cleaning including the removal of old paint, sand blasting is the best and usually the least expensive method for equally good results. To do effective sand blasting a nozzle with a ¼ in. diameter orifice should be used. This will require an air supply of at least 100 cubic feet of free air per minute with a pressure just ahead of the nozzle of at least 90 psi. A lower pressure will not do economical or effective blasting.

With the suggested equipment from two to three square feet of surface can be cleaned per minute (actual blasting time) with a sand consumption of about 50 pounds per 100 square feet of surface cleaned, based on screening and using the sand twice. The sand should be purchased especially for blast cleaning and should be of a hard sharp silica type from 20 to 40 mesh grain size. The surface should be cleaned until it is a uniform gray color without discolored spots or areas. The insides of all pits should be blasted until clean.

Sand blasting is usually the best method of removing an old coat of paint because it does it economically and at the same time cleans the steel surface. In cases where blast cleaning cannot be used because the dust and grit are objectionable, the old paint may be removed by burning with a blow torch or with the oxyacetylene torch or with paint strippers. Paint strippers are chemical cleaners usually used with a high pressure steam generator and will remove large areas of paint economically. Before painting the stripped surface should be treated with a chemical rust remover and inhibitor such as specified in U. S. Dept. of Commerce, Letter Circular 744, dated 2-26-44, "Painting Steel Potable Water Tanks."

Figure 1 illustrates a tank being blast cleaned. This tank is at Ambridge, Pa., and is used as a test of various kinds of blast cleaning and types of paint.

Figure 2 shows the same tank as Fig. 1 and illustrates a steel dolly which provides a very convenient platform for both blasting and painting.

Paint Application

After an area of convenient size, usually one day's work, has been cleaned as above, all bare places where steel is exposed should be brushed with one coat of rust inhibitive primer before any rusting or surface discoloration takes place. After the primer coat has dried hard such surfaces should be brushed or sprayed with one or two coats as specified. Surfaces which have not been previously painted or from which all the old paint has been removed should be protected with at least a three coat system. Where the old paint is in good condition, two additional coats are usually satisfactory.

No painting should be done with oil type paints when the temperature is below 35°F, or upon wet, frosty, or dirty surfaces. The paint should be mixed and thinned as recommended by the manufacturer. If sprayed on, suitable nozzles should be used for spraying, with pressure on the liquid and atomizing nozzle within the ranges recommended by the paint and equipment manufacturers. Sprayed paint should preferably be applied in two layers at right angles to each other to obtain more uniform thickness.

If brushed on, the paint should be applied in one direction and smoothed in a direction at right angles to produce a coating of more uniform thickness. Each coat should be applied to the specified minimum dry film thickness. The interior paint finish should be allowed to dry until hard before filling the tank with water. With an oil type paint this usually requires several days in a well ventilated tank. With quicker drying paints the time will be shorter.

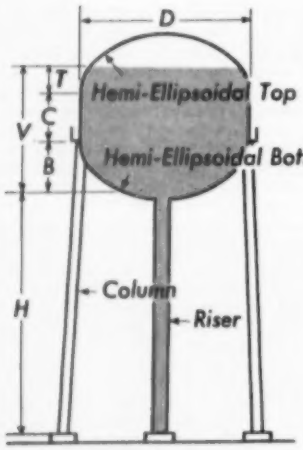
The question of whether brushing or spraying should be used is a subject of considerable discussion. It has been proved that on a clean surface spraying will produce a better paint coat than brushing because it will be more uniform in thickness, will not have depressions caused by brush bristles and will fill pits more uniformly. However, on a dusty or dirty surface the sprayed coat may lie on top of the dust and fail to adhere. Therefore, brushing is better for dirty surfaces because the brushing works the dirt into the paint and does not reduce adhesion. Spraying while fast and effective must be properly done. The correct air pressure, nozzle orifice and technique should be used. Where available workmen are not skilled in spraying paint it is safer to brush. If nearby property might be damaged by spray mist, brushing is advisable.

Capacities and Sizes of

STANDARD ELEVATED STEEL TANKS

by PITTSBURGH · DES MOINES

In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write—without obligation to our nearest office.



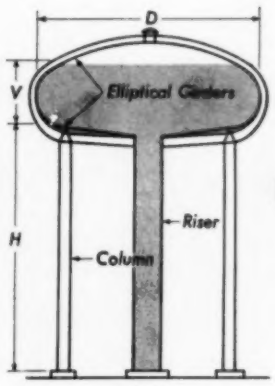
Double Ellipsoidal

TABLE I—DOUBLE ELLIPSOIDAL TANKS

Capacity U.S. Gallons	Tank Dimensions					Balcony Width	Number of Columns	Radial Bevel of Columns	Tower Height H
	D	V	B	C	T				
25,000	18'0"	14'4⅜"	4'9"	6'0⅛"	3'7⅛"	24"	4	1:12	see note**
30,000	18'0"	17'0"	4'9"	8'7¾"	3'7¼"	"	"	"	"
40,000	20'0"	18'6⅝"	5'2⅜"	9'4¼"	4'0"	"	"	"	4'0"
50,000	22'0"	19'2½"	5'11"	8'10⅜"	4'4⅜"	"	"	"	"
50,000	24'0"	16'8⅛"	6'4⅛"	5'6⅜"	4'9⅜"	"	"	"	"
60,000	24'0"	19'7½"	6'4⅛"	8'5⅜"	4'9⅜"	"	"	"	"
75,000	26'0"	21'2⅛"	6'10½"	9'1¼"	5'2⅜"	"	"	"	"
100,000	28'0"	23'8⅜"	8'7"	9'6½"	5'7¼"	"	"	"	"
100,000	30'0"	21'0⅜"	8'11"	6'1⅜"	6'0"	"	"	"	"
150,000	32'0"	27'4"	9'4⅛"	11'7"	6'4⅜"	"	"	"	"
150,000	34'0"	24'9⅜"	9'10½"	8'1⅜"	6'9⅜"	"	"	"	"
200,000	36'0"	29'4½"	10'6⅛"	11'8"	7'2⅜"	"	"	"	"
250,000	38'0"	33'0"	11'3⅜"	14'3¾"	7'4½"	30"	6	1:20	"
250,000	40'0"	30'10½"	11'10½"	8'6"	10'6"	"	"	"	"
300,000	44'0"	30'9"	13'0½"	7'11⅜"	9'8½"	"	"	"	"
400,000	48'0"	34'3⅜"	14'7"	11'0"	8'8½"	"	"	"	"
500,000	50'0"	39'0⅜"	15'6⅜"	15'5⅜"	8'0⅜"	"	8	"	"
500,000	55'0"	29'11"	12'0"	10'11"	7'0"	"	"	Vertical*	"
600,000	50'0"	45'10½"	15'6⅜"	22'3⅛"	8'0⅜"	"	"	1:20	"
750,000	60'0"	41'7⅜"	18'0"	11'10⅜"	11'9"	"	"	Vertical*	"
750,000	65'0"	37'0⅜"	20'1⅜"	6'5"	10'5½"	"	"	"	"
1,000,000	65'0"	47'1⅛"	20'1⅜"	16'5⅜"	10'5½"	"	10	"	"
1,000,000	70'0"	42'6½"	23'0"	10'9½"	8'9"	"	"	"	"
1,000,000	75'0"	35'0"	20'6"	8'6"	6'0"	"	"	"	"
1,250,000	70'0"	51'2⅜"	23'0"	19'5⅜"	8'9"	"	12	"	"
1,500,000	70'0"	59'10⅜"	23'0"	28'1⅞"	8'9"	"	"	"	"

* Standard practice is to make columns vertical for Double Ellipsoidal Tanks whose diameter exceeds 50 ft. However, their columns may be inclined if desired, in which case their radial bevel would be 1:20.

** Standard tower heights (H) are as follows:
Up to 50 ft. in even 2 ft. intervals,
from 50 ft. to 100 ft. in even 5 ft. intervals,
and over 100 ft. in even 10 ft. intervals.
Most common standard tower heights are 75 ft. and 100 ft.



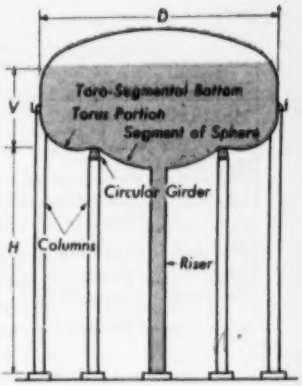
Obloidal

TABLE II—OBLOIDAL TANKS

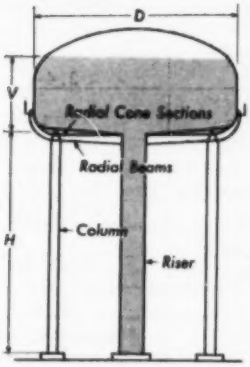
CAPACITY U.S. GALLONS	DIAMETER D	HEAD RANGE V	TOWER HEIGHT H
1,000,000	88' 0"	25' 0"	As Required
1,500,000	92' 0"	35' 0"	" "
2,000,000	106' 0"	35' 0"	" "

TABLE III—TORO-SEGMENTAL BOTTOM TANKS

CAPACITY U.S. GALLONS	STANDARD HEAD RANGES V			TOWER HEIGHT H
750,000	25' 0"			As Required
1,000,000	25' 0"	30' 0"	35' 0"	" "
1,500,000	25' 0"	30' 0"	35' 0"	" "
2,000,000		30' 0"	35' 0"	" "
2,500,000		30' 0"	35' 0"	" "
3,000,000		30' 0"	35' 0"	" "



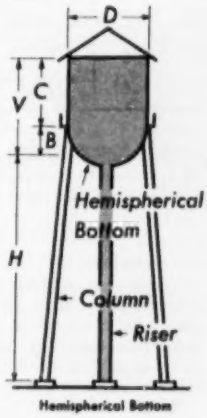
Toro-Segmental



Radial Cone

TABLE IV—RADIAL CONE BOTTOM TANKS

CAPACITY U.S. GALLONS	TANK DIMENSIONS D	V	NUMBER OF COLUMNS	TOWER HEIGHT H
300,000	53' 0"	20' 0"	8	As Required
500,000	60' 0"	25' 0"	"	" "
750,000	73' 0"	25' 0"	"	" "
750,000	67' 0"	30' 0"	"	" "
1,000,000	85' 0"	25' 0"	10	" "
1,000,000	77' 0"	30' 0"	"	" "
1,000,000	71' 0"	35' 0"	"	" "
1,250,000	95' 0"	25' 0"	12	" "
1,250,000	87' 0"	30' 0"	"	" "
1,250,000	80' 0"	35' 0"	"	" "
1,250,000	74' 0"	40' 0"	"	" "
1,500,000	103' 6"	25' 0"	"	" "
1,500,000	95' 0"	30' 0"	"	" "
1,500,000	88' 0"	35' 0"	"	" "
1,500,000	81' 6"	40' 0"	"	" "
2,000,000	108' 6"	30' 0"	16	" "
2,000,000	101' 0"	35' 0"	"	" "
2,000,000	94' 0"	40' 0"	"	" "
2,500,000	121' 6"	30' 0"	"	" "
2,500,000	112' 0"	35' 0"	"	" "
2,500,000	105' 0"	40' 0"	"	" "
3,000,000	123' 6"	35' 0"	20	" "



Hemispherical Bottom

TABLE V—HEMISPHERICAL BOTTOM TANKS

Capacity in U.S. Gallons	Tank Dimensions D	V	B	C*	No.** of Columns	Balcony Width	Tower height from foundation top level to bottom capacity level of tank (H)††						
5,000	9'0"	11' 0⅜"	1'2½"†	9' 9⅜"	4	None	31' 9"	38'3"	51'9"	58'9"	72'9"	79'9"	93' 9"	100' 9"
10,000	13'0"	11' 7¾"	6'0"	5' 7⅜"	4	None	30' 0"	40'0"	50'0"	60'0"	70'0"	80'0"	90' 0"	100' 0"
15,000	13'0"	16'10¾"	6'0"	10'10¾"	4	None	30' 0"	40'0"	50'0"	60'0"	70'0"	80'0"	90' 0"	100' 0"
20,000	13'0"	21' 8"	6'0"	15' 8"	4	None	30' 0"	40'0"	50'0"	60'0"	70'0"	80'0"	90' 0"	100' 0"
25,000	15'0"	19'10½"	5'4"	14' 6½"	4	18"	44' 8"	50'0"	69'8"	75'0"	94'8"	100'0"	125' 0"	
30,000	15'0"	23' 8¼"	5'4"	18' 4¼"	4	18"	44' 8"	50'0"	69'8"	75'0"	94'8"	100'0"	125' 0"	
40,000	17'0"	24'11¼"	6'8"	18' 3¼"	4	24"	46' 3"			75'0"	96'3"	100'0"	125' 0"	
50,000	19'0"	25' 6"	8'0"	17' 6"	4	24"	55' 0"	63'4"	75'0"	83'4"	91'8"	100'0"	120' 0"	140' 0"
60,000	19'0"	30' 3½"	8'0"	22' 3½"	4	24"	55' 0"	63'4"	75'0"	83'4"	91'8"	100'0"	120' 0"	140' 0"
75,000	21'0"	30' 6¼"	8'0"	22' 6¼"	4	24"	55' 0"	63'4"	75'0"	83'4"	91'8"	100'0"	120' 0"	140' 0"
100,000	24'0"	30'11⅜"	8'6"	22' 5⅜"	4	24"	50' 0"	63'1"	75'0"	79'7"	91'6"	100'0"	116' 6"	141' 6"
150,000	28'0"	34' 5⅜"	10'5"	24' 0⅜"	4	30"	54'10"	63'2"	75'0"	83'4"	91'8"	100'0"	120' 2"	140' 3"
200,000	32'0"	35'11½"	12'9"	23' 2½"	6	24"	54' 1"	62'5"	75'0"	83'4"	91'8"	100'0"	120'11"	141'10"

* This column lists height of tank cylinder up to high water level. The cylinder actually extends 3" higher.
† The bottom of this 5000 gallon tank is a segment of a 9 ft. radius sphere.
** Radial bevel of columns of 4 column towers is 1-$1\frac{1}{16}$:12; of 6 column towers 1:10.
†† Towers of heights other than those listed are available.

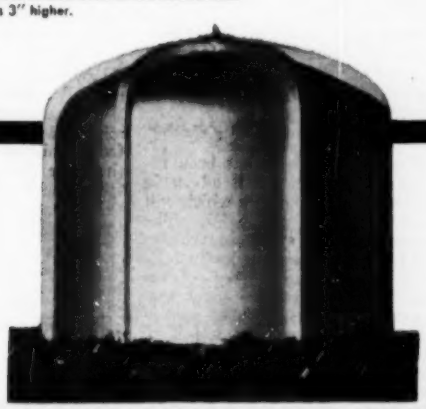


TABLE VI—STEEL RESERVOIRS

Capacity in U. S. Gallons	Diameter	Height
50,000	20'	21' 6"
60,000	22'	21' 6"
75,000	24'	22' 6"
100,000	26'	25' 6"
150,000	30'	28' 9"
200,000	34'	29' 9"
250,000	38'	29' 9"
300,000	42'	29' 3"
400,000	46'	32' 6"
500,000	50'	34' 6"
750,000	60'	35' 9"
1,000,000	70'	35' 0"
1,500,000	80'	40' 3"
2,000,000	95'	38' 3"
2,500,000	110'	35' 6"
3,000,000	120'	35' 9"
4,000,000	130'	45' 9"

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SANTA CLARA, CAL. . . . 625 Alviso Ro

PAINT SYSTEMS FOR INTERIOR SURFACES

Paint System No.		1.1*	1.2*	1.3*	1.4*
Must mill scale be removed		No	Yes	No	Yes
Number of Coats		2 or 3	2 or 3	2 or 3	4
1st Coat	Pigment	Red Lead-Iron Oxide	Red Lead	Red Lead-Lead Chromate**	Basic Zinc Chromate
	Vehicle	Linseed Oil-Alkyd	Phenolic	Phenolic	Vinyl
2nd and 3rd Coat	Pigment	Red Lead	Red Lead	Blue Lead-Zinc Oxide***	Red Lead
	Vehicle	Phenolic	Phenolic	Phenolic	Vinyl
4th Coat	Pigment	x	x	x	Aluminum
	Vehicle	x	x	x	Vinyl-Alkyd

PAINT SYSTEMS FOR EXTERIOR SURFACES

Paint System No.		2.1*	2.2*	2.3*	2.4*
Must mill scale be removed		No	Yes	No	Yes
Number of Coats		2 or 3	2 or 3	2 or 3	4
1st Coat	Pigment	Red Lead-Iron Oxide	Red Lead	Red Lead-Lead Chromate	Basic Zinc Chromate
	Vehicle	Linseed Oil-Alkyd	Phenolic	Phenolic	Vinyl
2nd and 3rd Coat	Pigment	Aluminum, Black, Gray or Green	Aluminum, Black, Gray or Green	Aluminum, Black, Gray or Green	Red Lead
	Vehicle	Alkyd	Alkyd	Alkyd	Vinyl
4th Coat	Pigment	x	x	x	Aluminum, Black, Gray or Green
	Vehicle	x	x	x	Vinyl-Alkyd

*** See Appendix for detailed specifications for the paint systems outlined above.**
**** Used also for 2nd coat in the three coat system.**
***** Used as 2nd coat in two coat system but as 3rd coat in the three coat system.**

Health Hazards

To prevent disaster and damage to personal health the following precautions should be observed in repainting tanks.

SAND BLASTING. To avoid silicosis hazards men should wear masks with fresh air supply when working inside of closed or poorly ventilated tanks and should wear air filters at all other times.

CLEANING WITH SOLVENTS must not be done in unventilated spaces. All paint solvents produce toxic or suffocating vapors which usually are inflammable. Test atmospheres for inflammable conditions before and during cleaning with solvents.

PAINTING. Most paint vapors are hazardous to health and are inflammable, especially in closed spaces. Painters should wear fresh air masks. Ventilate sufficiently to avoid explosive atmospheres.

Paint Systems

Unless all of the old paint has been removed exposing clean metal it is advisable to repaint the tank with a primer which will be compatible with the old paint. The solvent action of many synthetic vehicles may lift and blister the paint underneath or adjacent to the area being painted. Some of the more recently developed paint systems give excellent protection, but only if applied over steel surfaces from which all mill scale and old paint have been removed by blasting. Recommended paint systems for steel water tanks are shown in the accompanying charts—"Paint Systems for Interior and Exterior Surfaces."

Paint Maintenance

A tank should be inspected at least once a year. The tank should be drained and the interior allowed to dry so that the paint can be properly inspected. Defects in the paint coat such as blisters, rust, or abraded spots should be repaired so that they will not progress to extended failure of the paint film.

If the mill scale has been previously removed the defects which appear in the paint film will usually be very small in area and will mostly be the result of abrasion or minor blistering. These small areas should be cleaned and repainted with the same materials with which they were painted originally.

Thorough annual inspection and spot painting in this manner will materially increase the life of the paint system, and complete repainting should not be necessary for several years. There will be very little deterioration of the steel and the tank should last indefinitely.

If the mill scale has not previously been removed, the surfaces should be examined carefully to determine whether the defects are due to incidental abrasive damage or to mill scale lifting. Mill scale usually fails from moisture getting under it and lifting the scale and the paint on top of it away from the steel surface. This exposes a rusted area under the mill scale resembling improperly cleaned steel.

If there are only a few defects, these should be cleaned and repainted as above, but if there are mill scale failures occurring over the entire tank it would be unwise to clean and repaint these spots because this type of failure is progressive and more spots will continue to appear. It is then a never ending job to properly repair the paint film. In such a case it is advisable to completely remove the old paint film and the remaining mill scale by sand blasting, and to repaint such sandblasted surfaces.

The American Water Works Assn. has published a "Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs," Publication No. 7H, 2-5, latest revision. Copies may be obtained by addressing the Association at 500 Fifth Avenue, New York 18, N. Y. These recommendations were published in the AWWA Journal for October, 1948.

Appendix

1. DETAILS OF PAINT SYSTEMS RECOMMENDED FOR INTERIOR SURFACES.

1.1 For use over clean steel or clean tightly adhering mill scale and tightly adhering old paint:

1.11 First Coat:

Paint: Red Lead-Iron Oxide primer in a linseed oil-alkyd vehicle.

Specification: Federal Spec. TT-P-86a-Type II.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This paint dries for handling or recoating in about 16 hours. The vehicle consists of raw linseed oil blended with a glyceryl-phthalate type varnish composed of a linseed oil modified alkyd resin with the necessary driers and volatile thinners. The free linseed oil in this paint has more wetting power than the type IV, for better bonding with the metal surface and for sealing the mill scale.

1.12 Second Coat:

Paint: Red Lead primer in a phenolic vehicle.

Specification: Federal Spec. TT-P-86a-Type IV.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This paint has excellent water impermeability and exhibits good resistance to acid and alkaline environments. It dries for handling or recoating in about 6 hours. The vehicle for this paint is a straight phenolic spar varnish suitable for grinding with red lead and consists of a varnish composed of 25 gallons of tung oil and 100 pounds of a 100% pure non-harden-

ing phenolic resin plus the necessary driers and volatile thinners.

1. 13 Third Coat:

Paint: Same as second coat item 1. 12.

Note: Three coat paint systems are recommended if the old paint has been entirely removed. Where the old paint is in good condition, a two coat repaint system is satisfactory but the total paint film thickness after repainting should not exceed about 10 mils.

1. 2 For use where mill scale and old paint have been removed by blasting:

1. 21 First Coat:

Paint: Red Lead primer in a phenolic vehicle.

Specification: Federal Spec. TT-P-86a-Type IV.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as for paint in item 1. 12.

1. 22 Second Coat:
1. 23 Third Coat:

Same as first coat item 1. 21 except that successive coats of paint should be tinted to slightly different colors to help indicate proper coverage.

1. 3 For use whether or not mill scale and old paint have been removed:

1. 31 First Coat:

Paint: Lead Chromate-Red Lead primer in a spar varnish vehicle.

Specification: Pgh-Des Moines Spec. S16482-37.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This paint was rated 100% in both the Ambridge and the Mahoning Valley paint tests. It is designed to have a dull orange surface which provides better adhesion for succeeding coats of paint. It dries for handling or recoating in 24 hours.

1. 32 Second Coat:

Same as first coat 1. 31 but tinted to help indicate proper coverage.

Note: In a two-coat system omit this coat.

1. 33 Third Coat:

Paint: Lead Chromate-Sublimed Blue Lead-Zinc Oxide-Graphite in a water resisting spar varnish vehicle.

Specification: Pgh-Des Moines Spec. F16502-38.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: This synthetic gray enamel was rated 100% in the Ambridge tests and 75% in the Mahoning Valley tests.

1. 4* For use where mill scale and old paint have been removed by blasting: (See note following 2. 44)

1. 41 First Coat:

Paint: Zinc Chromate primer in a vinyl vehicle, with an acid diluent.

Specification: Bureau of Ships Paint Formula 117.

How Applied: Spray.

Film Thickness: 0.3 to 0.5 mils.

Description: This metal conditioning wash primer is designed to dry for handling or recoating in 15 to 30 minutes. One part of a phosphoric acid-alcohol diluent is mixed with four parts of the insoluble basic zinc chromate-polyvinyl butyral resin base just before using. It must be used within 8 hours.

1. 42 Second Coat:

Paint: Red Lead primer in a vinyl vehicle.

Specification: Bureau of Ships Paint Formula 119.

How Applied: Spray.

Film Thickness: 1.0 to 1.5 mils.

Description: This anti-corrosive primer dries for handling or recoating in 30 minutes.

1. 43 Third Coat:

Same as second coat item 1. 42 but tinted brown to help indicate proper coverage.

1. 44 Fourth Coat:

Paint: Aluminum powder in a vinyl resin vehicle.

Specification: "Vinylite" Formula XE-5221A.

How Applied: Brush or Spray.

Film Thickness: 1.0 mils minimum.

Description: This paint is available ready to mix or in double compartment containers.

2. Details of Paint Systems Recommended for Exterior Surfaces.

2. 1 For use over clean tightly adhering mill scale and tightly adhering old paint:

2. 11 First Coat:

Paint: Red Lead-Iron Oxide primer in linseed oil-alkyd vehicle.

Specification: Federal Spec. TT-P-86a-Type II.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as paint in item 1. 11.

2. 12 Second Coat:

Paint: Aluminum, Black, Gray or Green in an alkyd vehicle.

Specification: Aluminum per PDM Spec. F16430-39, Black per PDM Spec. F16431-39, Gray or Green per PDM Spec. F16433-49.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: The aluminum paint consists of 2 pounds of Aluminum paste per Federal Spec. TT-A-466 Type A in one gallon of glyceryl phthalate alkyd resin vehicle per PDM Spec. 16434-39. The black paint consists of carbon black in the same alkyd vehicle. The gray and green tinted paints consist of titanium dioxide together with reinforcing and tinting pigments in the same alkyd vehicle.

2. 13 Third Coat:

Same as second coat item 2. 12 but tinted to help indicate proper coverage.

2. 2 For use where mill scale and old paint have been removed by blasting:

2. 21 First Coat:

Paint: Red Lead primer in a phenolic vehicle.

Specification: Federal Spec. TT-P-86a-Type IV.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as paint in item 1.12.

2. 22 Second Coat:
2. 23 Third Coat:

Aluminum, Black, Gray or Green in an alkyd vehicle, same as paint in item 2. 12.

2. 3 For use whether or not mill scale and old paint have been removed:

2. 31 First Coat:

Paint: Lead Chromate-Red Lead primer in a spar varnish vehicle.

Specification: Pgh-Des Moines Spec. S16482-37.

How Applied: Brush or Spray.

Film Thickness: 1.5 mils minimum.

Description: Same as paint in item 1. 31.

2. 32 Second Coat:
2. 33 Third Coat:

Aluminum, Black, Gray or Green, in an alkyd vehicle, same as paint in item 2. 12.

2. 4* for use where mill scale and old paint have been removed by blasting: (See note following 2.44.)

2. 41 First Coat:

Paint: Zinc Chromate primer in a vinyl vehicle, with an acid diluent.

Specification: "Vinylite" Formula WP-1.

How Applied: Spray.

Film Thickness: 0.3 to 0.5 mils.

Description: Same as paint in item 1. 41.

2. 42 Second Coat:

Paint: Red Lead primer in a vinyl vehicle.

Specification: "Vinylite" Formula XE-5295.

How Applied: Spray.

Film Thickness: 1.0 to 1.5 mils.

Description: Same as paint in item 1. 42.

2. 43 Third Coat:

Same as second coat item 2. 42 but tinted brown to help indicate proper coverage.

2. 44 Fourth Coat:

Paint: Aluminum, Black, or Gray in a vinyl-alkyd vehicle.

Specification: Aluminum per "Vinylite" Formula XE-5221A, Black per "Vinylite" Formula XE-5296, Gray per "Vinylite" Formula XE-5297.

How Applied: Brush or Spray.

Film Thickness: 1.0 mils minimum.

Description: The aluminum paint is available ready to mix or in double compartment containers. The gray paint complies with Bureau of Ships Paint Formula 122. All of these topcoats are quick drying like the vinyl red lead primer. They are much more readily sprayed than brushed although special thinners may be used to improve brushability.

Paint Sources

The specifications referred to in the details of paint systems above may be secured from the following sources:

U. S. Government Specifications—the Superintendent of Documents, Government Printing Office, Washington, D. C.

Pittsburgh Des Moines Specifications—Pittsburgh Des Moines Steel Company, Pittsburgh 25, Pa.

Bakelite Division of Union Carbide and Carbon Corporation, 30 East 42 Street, New York, New York.

To secure the above paints it is only necessary to purchase them from a reliable paint manufacturer who will agree to furnish paints strictly in accordance with the specifications referred to. Where company specifications are given, the company will usually advise the names of current suppliers of paints known to be satisfactory.

*Vinyl Paint Systems No. 1.4 and 2.4 were developed during World War II for painting ship bottoms. They were adopted by the U. S. Navy and Coast Guard who have prepared specifications for their use. These paints are more difficult to apply than oil type paints and require spraying technique similar to lacquers. When properly applied on blasted surfaces they will last much longer than oil type paints. The Vinyl System for ship bottoms is credited with extending the repainting time for ocean going ships from less than one year to over two years.

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SPRAYING METHODS FOR DISINFECTION OF SMALL TANKS

Produces Thorough and Economical Results

By HARRY W. TRACY and EDW. L. FONSECA
Engineers, Water Purification Division
San Francisco Water Dep't., San Francisco, Calif.

IN a paper* presented at one of the California Section's Regional Meetings of the AWWA methods of disinfecting tanks and reservoirs were discussed. As the last of three basic methods a spray method was described which was then relatively new and little in the way of experience could be given at the time. Basically this method consisted of using a gas-type high pressure solution feed chlorinator to supply a heavily chlorinated water stream to a nozzle. The inside of the tanks were sprayed with this solution of approximately 500 ppm chlorine.

In a prepared discussion of this paper Herbert P. Nilmeier, Senior Sanitary Engineer, 12th Naval District, San Francisco, adaptations of the spray method to small tanks were presented. As these variations of the basic spray method were in the form of a discussion they were not published. Since these modifications would seem to be very useful to many waterworks operators, the present authors are attempting to cover the original discussion and present new data collected in the interim.

Fundamentally this disinfection procedure is most adaptable to small relatively low tanks; especially where cost, time or drainage of chlorinated water are limiting factors.

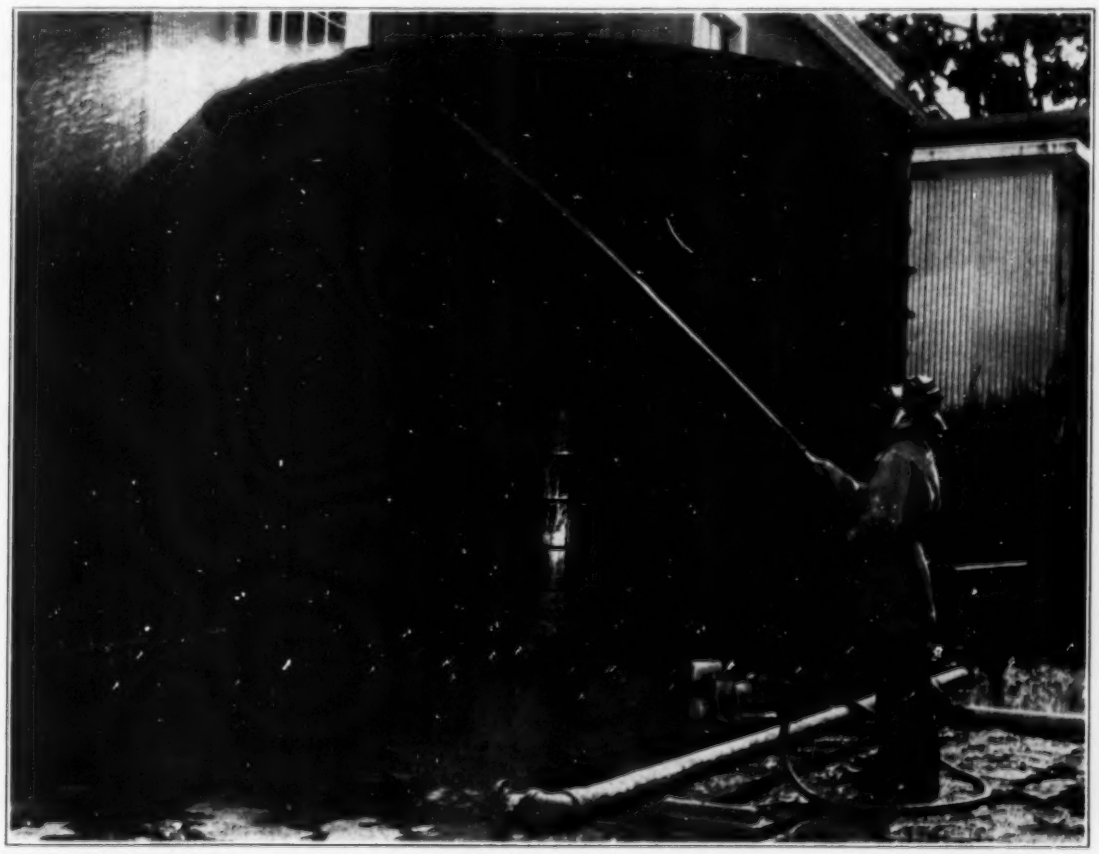
The Procedure

The procedure consists of making up a 500 ppm chlorine solution with calcium hypochlorite powder such as "H.T.H.," "Perchloron," etc., which will contain roughly 500 ppm of available chlorine, and spraying this solution on the sides and roof of the tank to be disinfected with either a hand pump or small leak pump, the latter probably being the most readily available.

In several instances the following procedure was satisfactorily used for small tanks. A chlorine solution was made up on the bottom of the tank by filling the tank with about one foot of water and adding the correct amount of calcium hypochlorite to give a solution containing roughly 500 ppm of available chlorine. Mixing was done by stirring with a broom. A civilian defense stirrup pump was then filled with this solution and the interior of the tank sprayed intermittently over a two hour period.

Under these conditions the bottom of the tank, the location of the maximum contamination, is continuously covered by the sterilizing solution. The sides and top, which are usually comparatively clean, will have various periods of contact with the

* "Methods of Disinfecting Tanks and Reservoirs" H. W. Tracy, J. A.W.W.A. 43, 85.



DEMONSTRATION of Spray Method of tank disinfection, showing Homelite leak-pump, and what the well dressed "spray-disinfector" will wear.

hypochlorite solution during the two hours. These contact periods have been found sufficient for tank disinfections in all cases encountered.

Where the tanks were larger, and the location of the tank drain lines correct, the authors made up several hundred gallons of hypochlorite solution and placed a 50 gallon drum under the tank drain. This drum served as a suction reservoir for a 1½" leak-pump which supplied the pressure to spray the tank. On the suction side of the pump standard hose was used, while on the discharge side one-inch hose was utilized with a ¼ x 2 inch nipple serving as the nozzle. All reducers, etc., were standard pipe fittings. As this type of hook-up is usually readily available it has been used on all tank disinfections utilizing the leak-pump. In those instances where a maximum height of stream is desired a standard ¾" fire nozzle may be used to good advantage. Since the hypochlorite solution drains from the tank walls and runs out of the tank drain it replenishes the suction reservoir. The photograph shows an operator preparing to enter a tank which is to be disinfected by spraying, using a readily portable 1½" Homelite leak-pump. In this instance the pump suction is taken directly from the tank drain line.

The operator must wear a gas mask and should wear rubber boots, rain coat and hat while spraying the interior of the tank. Otherwise, no special safety precautions need be used with the pump. However, there is one precaution, the exhaust from the pump engine must not enter the tank, since most gas mask cannisters used in chlorine service will not protect the wearer from carbon monoxide fumes.

In recirculating the chlorine solution in this manner the strength of the solution should be checked periodically and if necessary more hypochlorite added to maintain the desired chlorine concentration.

Pump Corrosion

Although leak-pumps have been used in disinfection procedure without any noticeable deleterious effects, more concrete evidence on probable damage to the pump due to corrosion seemed desirable. Consequently, parts of Homelite leak-pumps were obtained, cut into coupons and immersed for various periods of time in a 500 ppm chlorine solution made from "H.T.H." It should be noted at this time that due to the high pH value in calcium hypochlorite solutions the disinfecting power is milder and also the amount of corrosion is very much less as compared with chlorine solutions made by dissolving chlorine gas in water.

The weighed and calipered coupons were immersed in 500 ppm available chlorine solutions made from high test calcium hypochlorite (H.T.H.) for seven days, after which time they were carefully examined and dried. Any corrosion products were removed by brushing with a nylon bristle brush and the sample was then reweighed and recalipered to note any changes.

Coupons made from the pump casing (an aluminum alloy) showed no visible effects of corrosion on those faces which were not broken or machined. The machined and broken sides showed some corrosion with the latter surface showing the greater noticeable effects, i.e., the adherence of a gelatinous aluminum compound. From the tests run the casing coupons gained on the average of 0.0053 grams per square inch of exposed surface, the gain no doubt being from incomplete removal of the products of corrosion.

In the case of the coupons made from the pump impeller, which is of cast steel, the formation of corrosion products was much more noticeable, but here again it was the machined and broken surfaces that were being attacked. The impeller coupons lost an average of 0.027 grams per square inch of exposed surface.

In both of the above cases no change could be noted in the caliper readings down to 1/1000 inch taken before and after the tests. In actual practice the rate of corrosion would be speeded up due to the velocity of the water washing away the corrosion products, but on the other hand the corrosion would be retarded by the oxides of iron and the aluminum and any oil films that might be adhering to the pump. Although the Homelite Corporation indicated they do not recommend these pumps for use in chlorine service it would appear from the above data that a standard Homelite leak-pump can be used with very little harm as a spray pump for tank disinfection, especially when the short contact times are considered. As a precaution, though, the pump and fittings should be thoroughly flushed immediately after use.

Conclusions

Although there is relatively little economic advantage in connection with tanks of less than 25,000 gallons capacity when this type of spray method is used, rather than filling a tank with 50 ppm chlorine solution. There *is* the advantage that very little water has to be dumped and the tank can be placed in service in a minimum of time, also all areas inside the tank will be covered by the disinfecting solution. On tanks from 25,000 to 100,000 gallons there is a distinct economic advantage in this hypochlorite spray method. For example, to fill a 100,000 gallon tank with 50 ppm hypochlorite solution the cost of wasted water and hypochlorite would be approximately $30.00, while the spray method costs would be under $3.00. Labor costs would be about the same in both cases. A minimum of time and expense is required to disinfect and put into service a water tank when the hypochlorite spray method is used.

The authors wish to express their appreciation to the Homelite Corporation of Port Chester, N.Y., for supplying pump sections for testing purposes.

PAINTING DAMP WATER PIPES

In reply to a question regarding the painting of plant piping which is wet from condensed moisture and cannot be taken out of service long enough to dry, The New Jersey Zinc Company prints the following in its periodical, "Paint Progress." The engineer, by the way, stated that wiping the pipes with dry rags before painting had not been satisfactory.

Says New Jersey Zinc:

"We have seen good results obtained by using a turpentine wash to replace the moisture on the pipes and have, as a result, adopted the following method in our own plants:

"The surface is prepared for painting by removing the loose paint and scale by wire brushing and scraping. The dirt and excess moisture are then wiped off the surface and a liberal coating of turpentine is applied.

"The turpentine has a two-fold effect: first to replace the water remaining on the surface by virtue of its preferential wetting property, and second, to 'lift' any loose rust scale remaining on the surface after the mechanical cleaning. A primer coat of standard Zinc Dust-Zinc Oxide paint is then applied directly on the turpentine wet surface, thus providing the necessary rust inhibitive coating. In actual practice, a considerable interval may be allowed between the application of the turpentine and the primer, since the turpentine prevents further condensation of water on the steel.

"Brush application of the primer is preferred to spray application, since it insures the intimate contact of the Zinc Dust with the surface. An 80:20 Zinc Dust-Zinc Oxide formula with a linseed oil vehicle has been used, but a synthetic vehicle, such as phenolic, may be preferable, first, because of the more rapid drying of the synthetic resin formulation, and second, because of the improved water resistance of the film.

"The usual drying interval is allowed, after which the finish coat paint is applied. Just before the application of the second coat, the moist surface is again wiped with turpentine, but care must be taken to avoid an excess of the turpentine, since it might soften the surface of the primer.

"Either an 80:20 Zinc Dust-Zinc Oxide paint or other suitable metal paint may be used as the finish coat. Colored Zinc Dust paints are available for finishing coats where a distinctive color scheme is desired.

"It has been found that kerosene may be substituted for turpentine to replace moisture on the pipes, but its action is much slower and its assimilation into the paint less positive."

BLOWING OUT SERVICE LINES

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

MOST every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company corrects that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street, to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb. working pressure) check valve.
(4) 1 (2,000-lb. working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.

Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

OPERATION OF PNEUMATIC STORAGE TANKS

by J. B. WILKINSON, M.E.
Chief Engineer
Fire Ins. Rating Bureau, Milwaukee, Wis.

A PNEUMATIC storage tank as used in municipal water works serves the twofold purpose of maintaining domestic pressures within a selected range and of supplying a continuous domestic demand with intermittent operation of a pump.

Low initial cost is amongst the reasons for selecting this type of storage instead of an elevated tank or reservoir. However, pneumatic storage is the most expensive type of water storage in terms of cost per gallon of storage. This is the case because, as will be shown later, the useful capacity within the desired pressure range is usually only a small fraction of the full volume of the tank, and also because the tank must be heavily constructed to withstand the maximum system pressure. It follows that pneumatic storage rarely is large enough to make an important contribution to fire protection, and the usual location is at or near the pumping station. On the other hand pneumatic storage may frequently be justified for betterment to water service on the fringes of water supply systems serving residential areas.

Typical main installations are found in small villages of a few hundred population. The horizontally-mounted tank is cylindrical in cross-section, has dished heads and access manhole, and fabrication conforming to the ASME code for unfired pressure vessels is indicated by stamped marking on the shell. Diameter may be 8 or 9 ft., and gross capacity 16,000 to 20,000 gallons. Larger or smaller tanks are used according to the size of the system. Connection is made from the bottom to a distribution main (a 4 in. pipe for such connection is ordinarily sufficient) and from the top to the compressor used to replenish the cushion air from time to time. The air line should have a renewable-disc angle globe valve at the tank, and toward the compressor a bronze-seat check valve and a brass pop relief valve of the same size as the pipe. The latter should be set to blow at 10 per cent above the maximum operating or design pressure of the tank, whichever is the smaller. A gage glass reveals the air-water level. Automatic operation of a pump is provided for by a pressure-actuated starter, or a float switch can be used.

Two or more tanks can be operated as a unit by connecting discharge and air lines to common headers. Such installations are not usual because one larger tank will provide equal storage at less cost.

Operating Considerations

Operators of pneumatic storage systems may be uncertain as to where the air-water level should be carried for best results. Operating conditions vary widely and there is no single answer which applies to every case. The objective is to secure the largest possible effective storage with the smallest possible variation from the average pressure wanted in the system. But relatively large volume is associated with a wide pressure range; conversely, close pressure regulation is obtainable only by lessening effective storage.

There is some minimum pressure that must be maintained to provide the desired service. This may be 40 lb. in a place where domestic supply is the principal consideration, or may be 60 lb. or more where buildings are high, topography irregular, or sufficient pressure for fire streams is wanted for the short time required to get an operator to a normally unattended pumping station.

Having decided upon the minimum required pressure, the next step is either to select the range of operating pressure, or to determine the storage neded to supply the demand without too frequent starting of the pump. The top pressure will be the governing consideration in some instances —as where certain areas are low and pressures correspondingly high. Or, when the demand is relatively large and approaches the capacity of the pump, the largest possible storage may be wanted to lengthen the operating cycle. But in any given installation, fixing either of these factors automatically affects the other.

Calculation of Pressure-Volume Relations

Air trapped above the water in a pneumatic storage tank is an elastic medium. Pressure-volume relations follow Boyle's law which, briefly stated, is that at constant temperature—approximately true in actual practice—the volume of the confined air multiplied by its absolute pressure gives a number which is always the same for the particular container holding the same amount (weight) of air.

This relation, expressed mathematically, is represented by the formula

$$PV = C,$$

where P is the *absolute** pressure in lb.
V is the *air volume* in any convenient unit, such as cubic feet or gallons.
C is a *constant*—that is, the fixed number referred to in the preceding paragraph.

To illustrate the application of this formula to a pneumatic equalizer, assume an 18,000-gallon tank containing 9000 gallons of air over water; the pressure gage shows 45 lb. The volume of the air is wanted when water is pumped in until the pressure is raised to 60 lb. gage. It will be convenient and sufficiently accurate to assume that atmospheric pressure (which must be added to the gage reading to give absolute pressure) is 15 lb.

$$C \text{ (is the constant)} = P \times V = (45 + 15) \times 9{,}000 = 540{,}000$$

Having determined this constant, the air volume at 60 lb. gage becomes

$$V = \frac{C}{P} \quad \frac{540{,}000}{(60 + 15)} = 7{,}200 \text{ gallons}$$

and the water stored is the tank capacity minus the air volume, or 10,800 gallons.

Chart of Pressure-Storage Relations

Numerical calculations of the sort shown are cumbersome, and several must be made to cover the entire operating range. The accompanying Pressure-Storage Relations Chart has been prepared to make such calculations unnecessary, and at the same time express the relations directly in terms of water volume and gage pressure.

The numbers on the lower horizontal axis are pressures as shown by the gage on the tank. Those on the left margin refer to the volume of water in the tank, expressed as a percentage of the total tank capacity.

If the operating condition at any time is indicated by a point on the chart at the intersection of a water-stored and a pressure line, corresponding pressure-storage relations when water is pumped in or withdrawn will lie along a diagonal line drawn through this point parallel to the several diagonals on the chart. These last are marked 0, 10, etc., the numbers indicating the residual pressure which will remain when the tank has been emptied without escape of air.

Uses of the Chart

Example I. Assume a 20,000-gallon tank to be half full at mean operating pressure of 50 p.s.i. gage pressure. This condition is represented by a point at the intersection of the 50 per cent storage and 50 lb. pressure lines. Through this point draw a parallel diagonal; it will be about midway between the 15 and 20 lb. diagonal lines. As water is pumped in or withdrawn, the pressure-storage relations will be along this line. Thus, if water is pumped in until the pressure is 60 p.s.i. gage, storage will be 57 per cent of the tank capacity, and if water is withdrawn until pressure falls to 40 lbs., storage will be only 41 per cent of full capacity. It follows that effective storage within the pressure range of 40 to 60 p.s.i. is the difference. In this instance it is 16 per cent (57-41) of 20,000 = 3200 gallons in the operating range of 20 lbs. around a mean of 50 lb.

Example II. Assume the tank and pressure range to be the same as in Example I, but that the operator wishes not to risk delivery of air to mains in case of power outage or failure of automatic pump controls. The diagonal line marked "0" applies to this condition. At 40 and 60 lbs. pressure, the tank will be filled to 72½ per cent and 80 per cent of full capacity at the respective pressures, and effective storage within this pressure range will be only 7½ per cent (80-72½) of 20,000 = 1500 gallons. Note that the low terminal pressure has been secured only by very substantial reduction in effective storage; this may not be objectionable if it does not cause too frequent operation of the pump. Or retaining the zero terminal pressure, more storage can be had by broadening the pressure setting.

Example III. Again considering the same tank and operating range of 20 lb. around a mean of 50 lb., maximum effective storage will be had when the tank is empty at the lower pressure setting. To provide a small margin of safety against delivery of air in normal operation, let us assume that the tank is conditioned for terminal pressure of 35 lb. (5 lb. below the pump starting pressure). On the diagonal for 35 lb. taken as the zero storage axis, storage of 9 per cent and 33 per cent will be found at 40 and 60 lb. pres-

*Absolute pressure is gage plus atmospheric pressure.

sure respectively. Effective storage is the difference (33-9), or 24 per cent of 20,000 = 4800 gallons. However, lacking an accessory device that would release the remaining air at a predetermined low water level in case the pump should fail to start, a conservative operator would probably prefer a condition more like that outlined in Example I or II wherein a lower storage valve is maintained.

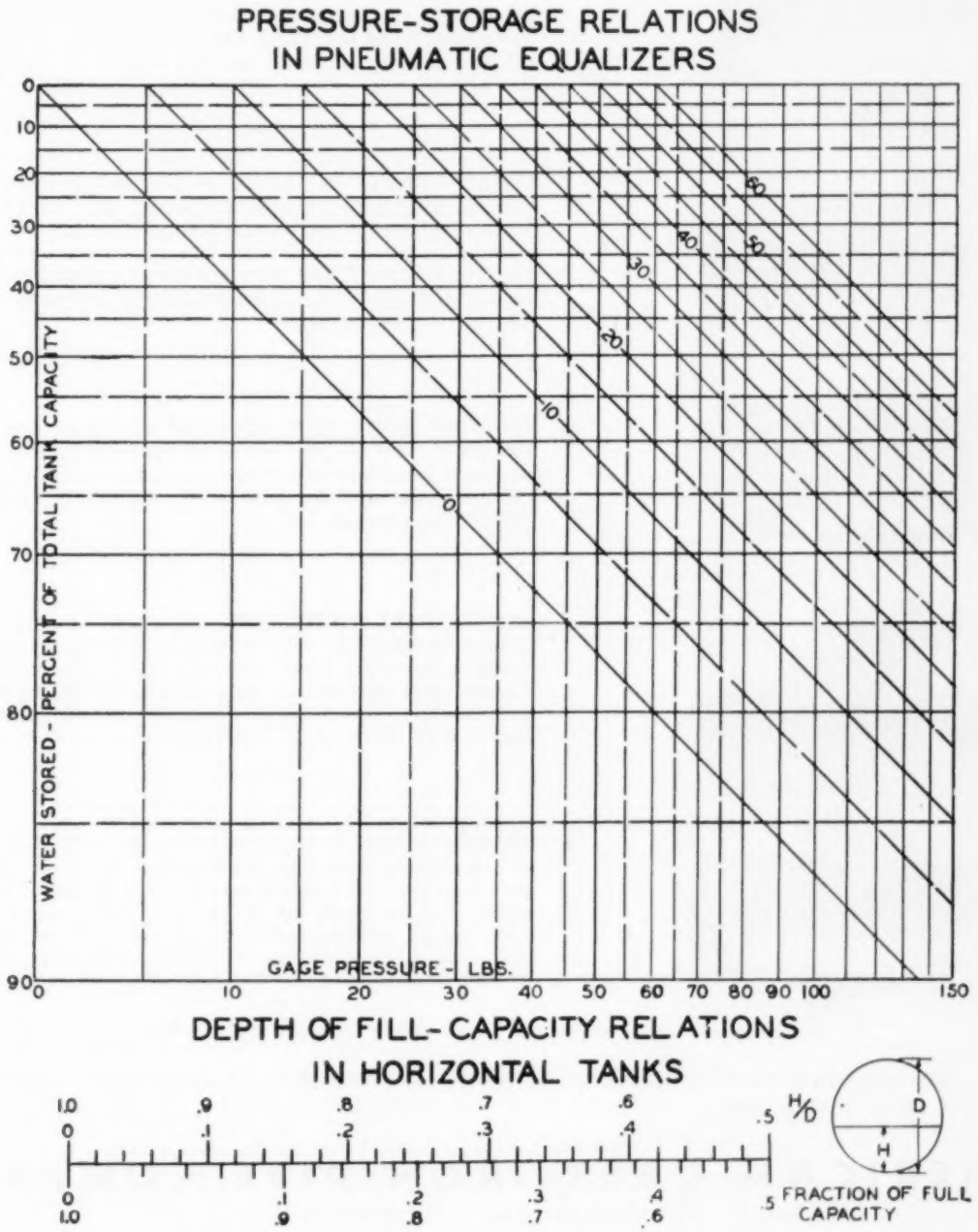
Water Depth-Volume Relationship

There remains the problem of relating water volume to the level carried in the tank. The Depth of Fill-Capacity scale at the bottom of the chart is for this purpose. It does not take account of the capacity in dished heads, but the error will be negligible for practical purposes.

This scale has dual markings, the inner numerals (those nearest the scale) applying to tanks less than half full, the outer figures to those more than half full.

The H/D scale above the central line indicates the extent to which the tank is filled as a decimal fraction or per cent of its diameter. The numerals below the line show the corresponding actual storage as a percentage of the full capacity of the tank.

To illustrate, assume a tank of 20,000-gallons gross capacity, and 96 in. diameter. If 24 in. of water is pumped in, the H/D fraction is 24/96=0.25. Corresponding to 0.25 *above* the scale bar the actual storage shown below the bar is only 0.2 or 20 per cent of full capacity—i.e., 4000 gallons. Since the tank was less than half full, the inner numerals were used. Similarly, if it is desired to fill this tank to 70 per cent of gross capacity locate 0.7 *below* the scale bar and the corresponding value of .665 for H/D will be found in the *upper* line. That is to say the tank must be filled to 66.5 per cent of its depth or .665 x 96 = 64 in. (approximately) above the bottom. In this case the outer numerals are used.

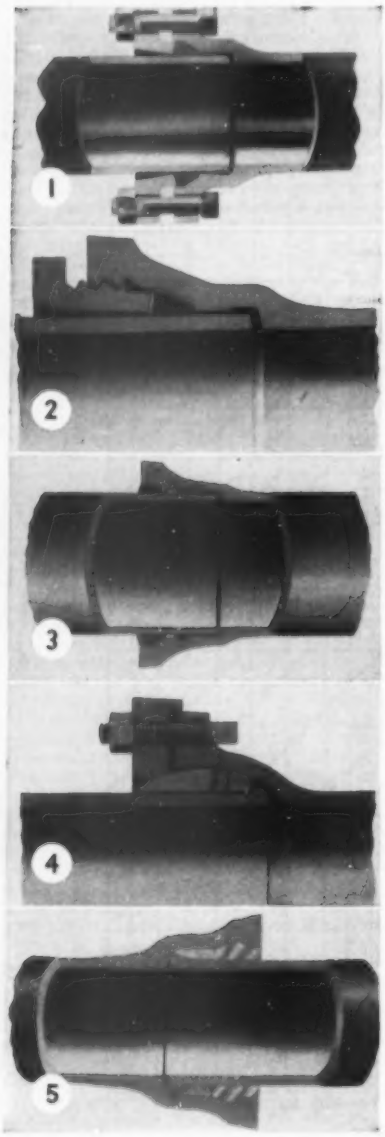


Pressure-Storage and Fill-Capacity Relations in Pneumatic Tanks

MONO-CAST CENTRIFUGAL PIPE

WITH JOINTS FOR EVERY SERVICE CONDITION

Mono-Cast Centrifugal Pipe can be supplied with joints for conveying gas, oil, sewage, water, and other liquids under every service condition. In most cases, these joints can be made up with unskilled labor and without special tools. Among the joints available are:



1. AMERICAN DOUBLE-X PIPE—A standardized *mechanical joint pipe* equipped with stuffing box type of joint having a ring gasket, cast iron gland, and cast iron bolts. Scientifically designed to meet the exacting requirements of low, medium and high-pressure service in handling gas and liquids.

2. SCREW-GLAND PIPE—An all-purpose economical, mechanical joint pipe suitable for water, gas, oil and other fluids, developed in answer to the demand for a rubber packed joint without bolts suitable for normal service and pressure conditions. Screw-Gland Pipe provides for liberal lateral deflection and provision for expansion and contraction of the pipe line without leakage.

3. ROLL-ON JOINT PIPE—Designed as an alternate for bell and spigot pipe for conveyance of water, sewage or similar liquids. It is quickly and easily assembled by unskilled labor and after assembly the joint will easily deflect and remain tight under pressure.

4. MOLOX BALL JOINT PIPE—An exclusive Acipco development, designed for river crossings and other installations requiring excessive joint deflection. It is positively locked against joint separation and remains bottle tight under pressures up to several hundred pounds per square inch at any angle within the range of deflection for which it is designed.

5. STANDARD BELL AND SPIGOT PIPE—Used under normal service conditions, the standard bell and spigot joint will give long and dependable service. The joints of bell and spigot pipe are made up of lead and jute, cement, or any other special jointing material customer may desire to use. It is supplied in diameters 3″ through 48″ inclusive.

Write for literature, stating the kind of joint in which you are interested. Address the ACIPCO office nearest you.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM 2, ALABAMA

Minneapolis Houston San Francisco Pittsburgh Kansas City New York City
Chicago Dallas Cleveland Los Angeles El Paso Seattle Denver

DESIGN OF MAIN EXTENSIONS OF SMALL SIZE

Where No Fire Service is Required

BY D. R. TAYLOR

General Manager, Baton Rouge Water Works Co., Baton Rouge, Louisiana

ALL public water utilities are occasionally confronted with the necessity of making main extensions. Where fire protection is required, design techniques and methods have been more or less standardized and generally accepted. Frequently, however, for numerous reasons well known to the profession, only domestic service will be required for a long time or at least for several years and a small main extension is decided upon.

To design a main extension for domestic service only, the maximum domestic demand must be known. During the last decade much attention has been given this subject. With the use of the Meter Master, many tests have been and are still being made in many sections, to determine maximum domestic demand, and the results vary so greatly that it is difficult to form a conclusion. The difference of climatic conditions in various sections will of course affect the results, but, a considerable variance has been found also in the same section in several parts of the country.

Property Classification and Water Consumption

For several years tests have been conducted in Baton Rouge by metering the total consumption of various numbers of residences of various classifications of property in an effort to determine maximum domestic demand. The Meter Master has been used in each test to record the various rates of flow. It has been desired to determine the maximum demand during the longest, hottest, driest, period that might occur within ten years, when lawn sprinkling reached a maximum. The ten year period was considered to be reasonable and practical. While several droughts occurred during the period of the tests, none was considered to be the ten year maximum. Realizing that lawn sprinkling can increase the demand enormously, a substantial percentage was added to the results to simulate maximum drought conditions for such a period.

While the rates shown have proved sufficient for this locality, it is felt that subsequent tests may suggest some slight downward revision for the larger numbers of houses in Classes 3 and 4. Based on these rates, however, a review of the design of more than twenty miles of small main extensions ranging in length from 100 to 3000 ft., installed during the last five years, has proved that these rates are adequate.

In Table 1, Class 1 may be of little use to the average city, on the other hand the author has assisted several small towns with populations of less than 5000 that were more rural than urban, where prospective customers desired only a minimum of service and where either they could afford very little expense for the main extension or the town had practically nothing in its budget to defray the expense of the installation. In these instances, Class 1 rates were satisfactory to all concerned. This class is included for those who are forced to resort to its use.

Table 1

Maximum Domestic Demand in G.P.M.

For various types of houses with tank-type toilets.

Number of Houses	CLASS OF PROPERTY			
	1	2	3	4
1	10	12	14	19
2	12	15	18	24
3	14	17	20	27
4	16	19	22	30
6	18	21	25	34
8	20	23	28	37
10	21	25	30	40
15	25	30	37	50
20	28	35	43	58
25	30	39	48	66
30	31	42	53	73
40	36	48	62	85
50	40	54	70	96
60	43	59	76	105
70	45	62	82	115
80	48	68	88	125
90	50	71	94	132
100	52	75	100	140
125	57	83	110	157
150	61	90	120	175
175	64	97	132	190
200	68	105	140	205
300	80	125	175	250
400	90	145	200	295
500	100	160	225	335

DESCRIPTION

CLASS 1 Sub-Standard houses with barest minimum of plumbing where little or no lawn sprinkling is expected.

CLASS 2 Small houses with one bath, on small lot. Small rental houses and small rental duplex houses. Very little lawn sprinkling. Either side of a duplex is considered as one house.

CLASS 3 Average good sub-division with 80% two to three bedroom houses with one bath and 20% two to three bedroom houses with two baths. Houses owned by occupant, with average amount of lawn and shrubbery requiring average amount of lawn sprinkling.

CLASS 4 Houses with three to four bedrooms and two to three baths on large lots requiring considerable lawn sprinkling. Does not include estates with or without swimming pools.

Loss of Head in Pipe

In Baton Rouge, raw water from deep wells has a total hardness of zero, a total alkalinity of 170, of which 150 ppm. is due to bicarbonates, a pH of 8.7 and requires no treatment. Mains 20 years old have a C of 120 or more.

The losses of head in Fig. 1 are based on actual inside diameter instead of nominal diameter. The sizes marked G. S. represent galvanized standard weight steel pipe. While all sizes of steel pipe are designated by nominal diameter, the various sizes of cast iron pipe are designated by actual diameter. This has been done for the following reason: All standard weight steel pipe is made to the same specifications by the various manufacturers, but the inside diameter of some small sizes of cast iron pipe varies with different manufacturers. Therefore, it seems appropriate to indicate the nominal diameter of galvanized steel pipe and actual diameter of cast iron pipe. In any event the actual diameter of the pipe being considered should be known. If it is desired to design with a C other than 120, the values in Fig. 1 should be multiplied by the proper multiplier shown in the following table:

Value of C	140	130	120	110	100
Multiplier	.75	.86	1.0	1.17	1.4

The small sizes of cast iron pipe are very popular for small main extensions because of the cast iron permanence and because of this small cast iron pipe can be salvaged, when replaced with larger mains to provide fire protection, and reused as often or as long as desired.

The curve in Fig. 2 was derived from the formula,

$$F = \frac{\Sigma N^m}{N^{m+1}}$$

Where N = Number of houses
m = 1.85

This formula was designed to determine the total friction loss in a pipe line with any number of outlets, an equal distance apart and all discharging at the same rate. (When N=1, F=1) It may be considered that these two conditions are satisfied when all of the lots are of the same width and all of the houses are of the same class. A slight variation in these conditions on a relatively

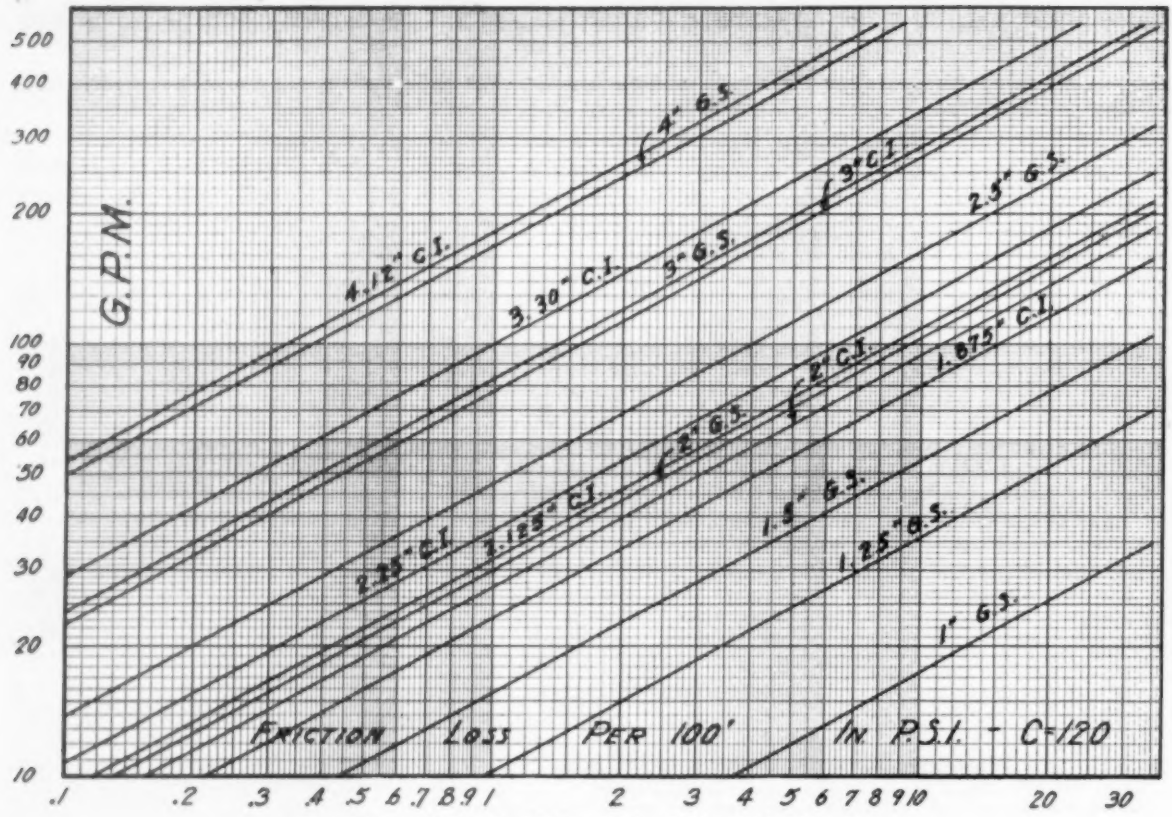


Fig. 1—Loss-of-Head in PSI per 100 ft. of Pipe With "C"= 120

short extension of one size will make little difference.

There may be rare instances, especially on a long extension, consisting of two sizes of pipe, when there may be some considerable variance in these two conditions along the extension or the width of the lots and/or class of houses may be different at either end of the extension. In such instances the use of a little practical judgment in making reasonable prorations to fit the conditions, will provide satisfactory results. In this case "N" is designated as the "number of houses," assuming that there is a separated outlet (tap) for each house.

When taps for two houses on opposite sides of the street are very close together on the main they should be considered as one "outlet" or "house" and the rate per house multiplied by two. For instance, if this condition existed for 40 houses (20 on either side of the street) on fifty foot lots along an extension 1000 ft. long, it should be considered that $N = 40 \div 2 = 20$. If these were Class 3 houses the rate per house (from Table 1) would equal $62 \div 20 = 3.1$ gpm.

The amount of residual pressure to be provided at the tap is a matter of opinion or policy. It may vary from 25 psi. for single story Class 2 houses to 40 psi. for two story Class 4 houses.

Total friction loss in a main extension for domestic service, expressed in pounds per square inch, equals length of the extension in hundreds of feet, times friction loss per 100 ft. in pounds per square inch, times factor (F). For example, assume that a 2-in. G.S. main with a C of 120, 500 ft. long, fed from only one end, serving 10 houses, has a maximum demand of 40 gallons per minute. What is the total friction loss in this main? From Fig. 1, friction loss for 2-in. G.S. pipe at 40 gpm. is 1.7 pounds per square inch per 100 ft. and from Fig. 2, for 10 houses F is .404. Therefore, total friction loss $= 5 \times 1.7 \times .404 = 3.43$ psi.

The Design Process

PROBLEM 1: A 1500 ft. main extension is required to serve 60 Class 2 houses on 50 ft. lots (30 on either side of the street) and the main will be fed from both ends. The daily minimum distribution system pressure is 50 psi. and a residual pressure of 30 psi. is desired at each tap. Therefore, only 20 psi. can be allowed for friction loss, 50—30=20. Assume that 1½ in. galvanized steel pipe with a C of 100 will be required.

1st Trial Calculation

From Table 1, maximum demand for 60 Class 2 houses = 59 gpm.
From Fig. 1, friction loss through 1½ in. G.S. pipe for 59 gpm. = 11.8 psi per 100 ft.
From Fig. 2, for 60 houses, F = 0.358.

Values in Fig. 1 are for a C of 120 and must be multiplied by 1.4 for a C of 100. This extension will be fed from both ends, therefore the total friction loss calculated as if it were fed only from one end must be divided by $2^{1.85}$ i.e., (3.6) or multiplied by the reciprocal of $2^{1.85}$ i.e., (.278).

Total friction loss
$15 \times 11.8 \times 1.4 \times .358 \times .278 = 24.66$ psi.

This exceeds the friction loss of 20 psi. that can be allowed, so the calculation should be repeated for pipe a size larger, as for instance 2 in. cast iron pipe.

2nd Trial Calculation

From Fig. 1, friction loss through 2 in. C.I. pipe for 59 gpm.
= 4.2 psi. per 100 ft.

Total friction loss
$= 15 \times 4.2 \times 1.4 \times .358 \times .278 = 8.75$ psi.

A 2 in. cast iron main will satisfy the maximum demand with a residual pressure of approximately 41.25 psi. at the taps.

PROBLEM 2: A 3000 ft. extension is required to serve 120 Class 3 residences on 50 ft. lots. The daily minimum distribution system pressure is 60 psi. and a residual pressure of 35 psi. is desired at each tap. Therefore, only 25 psi. can be allowed for friction loss, 60—35=25.

From Table 1, maximum demand for 120 Class 3 houses=108 gpm.* Assume that 1500 ft. of 3.30 in. cast iron and 1500 ft. of 2½ in. cast iron pipe with a C of 120 will be required.

1st Trial Calculation

1500 ÷ 50 × 2 = 60 houses on 3.30 in. main
1500 ÷ 50 × 2 = 60 houses on 2½ in. main
108 ÷ 120 = 0.9 gpm. per house
60 × 0.9 = 54 gpm. = maximum demand for 3.30 in. pipe
60 × 0.9 = 54 gpm. = maximum demand for 2½ in. pipe

Average rate of flow through the 3.30 in. pipe equals influent rate, plus effluent rate, plus rate per house, divided by 2.

Influent rate of 3.30 in. pipe =	108.0 gpm.
Effluent rate of 3.30 in. pipe =	54.0 gpm.
Rate per house	.9 gpm.
Total	162.9 gpm.

Average rate through 3.30 in. pipe
$= 162.9 \div 2 = 81.45$ gpm.
From Fig. 1, loss through 3.30 in. pipe for 81.45 gpm.
= .67 psi. per 100 ft.

*By interpolation

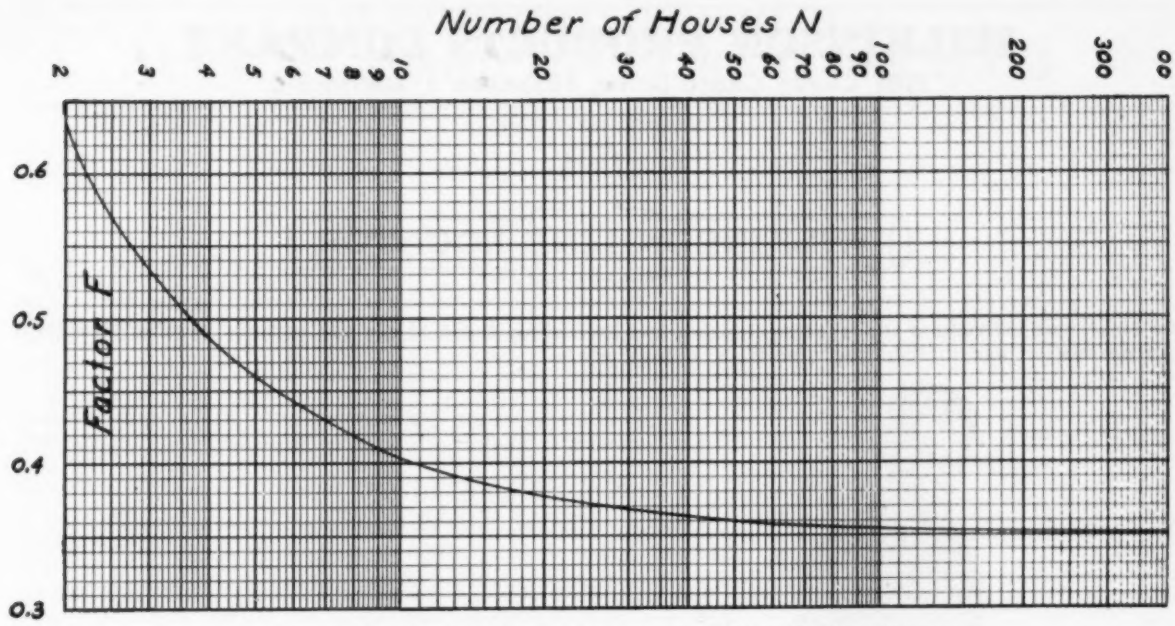


Fig. 2—Loss-of-Head Curve for Determining Factor for Various Numbers of Houses.

Therefore, total loss through the 3.30 in. pipe
= 15 × .67 = 10.05 psi.
From Fig. 1, loss through 2½ in. pipe for 54 gpm.
= 2.7 psi.
From Fig. 2, for 120 houses
F = .355
Therefore, total loss through 2½ in. pipe
= 15 × 2.7 × .355 = 14.35 psi.
Total loss through 3.30 in. and 2½ in. pipe
= 10.05 + 14.35 = 24.40 psi.

An extension consisting of 1500 ft. of 3.30 in. pipe and 1500 ft. of 2½ in. pipe will satisfy the maximum demand with a residual pressure of approximately 35.60 psi. at the taps.

PROBLEM 3: A 3000 ft. extension is required to serve 120 Class 3 houses on 50 ft. lots. The daily minimum distribution system pressure is 50 psi. and a residual pressure of 25 psi. is desired at each tap. Therefore, only 25 psi. can be allowed for friction loss, 50—25=25. The taps for each pair of houses on opposite sides of the street will be made within one foot of each other, along the main. In this case the extension will be fed from *both* ends and it is desired to use as much 2 in. galvanized steel pipe as possible and as little of the next larger size as will be required.

From Table 1, maximum demand for 120 Class 3 houses=108 gpm. Assume that 500 ft. of 2½ in. and 2500 ft. of 2 in. galvanized steel pipe with a C of 120 will be required.

1st Trial Calculation

500 ÷ 50 = 10 houses on 2½ in. main
(Each pair of taps made close together)
2500 ÷ 50 = 50 houses on 2 in. main
10 + 50 = 60
108 ÷ 60 = 1.8 gpm. per house
10 × 1.8 = 18 gpm. = maximum demand for 2½ in. pipe
50 × 1.8 = 90 gpm. = maximum demand for 2 in. pipe
Influent rate of 2½ in. pipe = 108.0 gpm.
Effluent rate of 2½ in. pipe = 90.0 gpm.
Rate per house = 1.8 gpm.
Total = 199.8 gpm.
Average rate thru 2½ in. pipe
= 198.8 ÷ 2 = 99.9 gpm.
From Fig. 1, loss thru 2½ in. pipe for 99.98 gpm.
= 4 psi.
Therefore, total loss thru the 2½ in. pipe
= 5 × 4 = 20.0 psi.
From Fig. 1, loss thru 2 in. pipe for 90 gpm.
= 7.7 psi.
From Fig. 2, for 60 houses
F = .358
Therefore, total loss thru the 2 in. pipe
= 25 × 7.7 × .358 = 68.9 psi.
Total loss thru 2½ and 2 in. if fed from one end
= 20.0 + 68.9 = 88.9 psi.
Total loss if fed from both ends
= 88.9 × .278 = 24.7 psi.

This extension will satisfy the maximum demand with a residual pressure of approximately 25.3 psi.

The values shown in Table 1 are not considered to be the perfect answer. The matter of maximum domestic demand may never be reduced to an "exact science." Considerable research, however is being conducted in various sections of the country and results are looked forward to by the profession with much interest. The values used herein have been obtained in a southern state where the growing season is long and the summer temperature is high. There are many garden clubs and an amazing interest is shown in growing semi-tropical plants, including camellias which may cost as much as $50.00 each, for a rare variety, several years old. For obvious reasons there is considerable sprinkling. Therefore, these maximum domestic demand values may be slightly high for other sections of the country.

These values are offered as a basis for further study and for use in design, until such values are determined for the particular section in which they may be used, if conditions in that section require that other values be used.

Useful Information

1 cubic foot of water @ 62° F.	=	Weighs 62.36 pounds
1 U. S. gallon of water @ 62° F.	=	Weighs 8.33 pounds
1 U. S. Gallon	=	.231 cubic inches
1 U. S. gallon	=	.0.13367 cubic feet
1 cubic foot	=	.7.48 U. S. gallons
1 Imperial gallon	=	1.2003 U. S. gallons
1 litre	=	0.26417 U. S. gallons
1 cubic meter	=	264.2 U. S. gallons
1 foot depth of water @ 62° F.	=	0.433 lbs. (per sq. in.) pres.
1 pound (per square inch) pressure	=	2.309 feet depth of water
1 horsepower	=	550 foot pounds per second
1 horsepower	=	33,000 foot pounds per min.

1 kilowatt	=	1000 watts
1 kilowatt	=	1.341 horsepower
1 horsepower	=	0.7457 kilowatts
1 cubic inch cast iron		Weighs 0.260 pounds
1 cubic foot cast iron		Weighs 450 pounds
1 cubic inch steel		Weighs 0.2835 pounds
1 cubic foot steel		Weighs 490 pounds
1 cubic foot cement (1 bag)		Weighs 90 pounds
1 cubic yard sand		Weighs 2700 pounds approx.
1 cubic yard gravel		Weighs 2700 pounds approx.
1 cubic foot common brick		Weighs 120 pounds approx.
1001 brick		Weigh 5300 pounds approx.

Formulas for Calculating Areas and Volumes

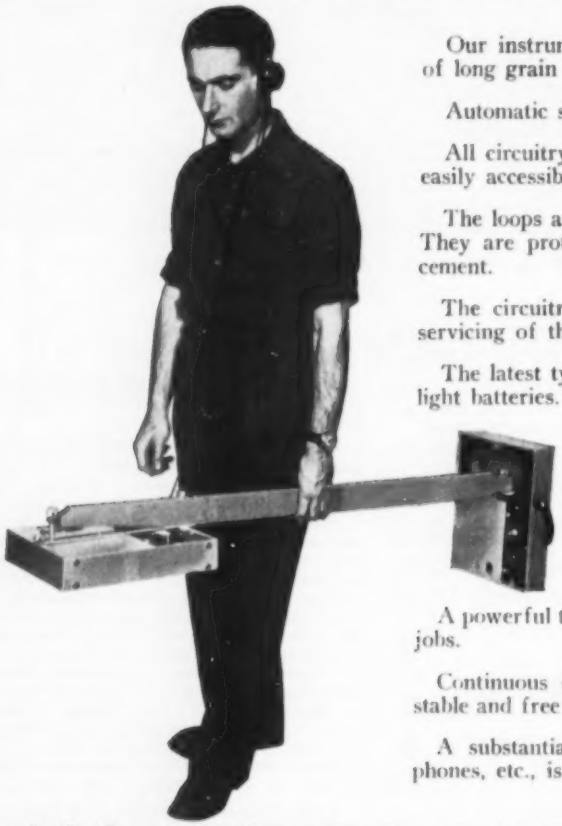
π	=	3.1416
Circumference of circle	=	Diameter × π
Area of circle	=	Radius² × π
Area of sphere	=	4 × radius² × π
Volume of sphere	=	⅔ × diameter³ × π
Area of PDM hemi-ellipse	=	1.237 × (diameter of tank)²
Volume of PDM hemi-ellipse	=	0.17431 × (diameter of tank)³
Area of cone or pyramid	=	Perimeter of base × ½ slant ht.
Volume of cone or pyramid	=	Area of base × ⅓ of height perpendicular to base
Area of frustrum of cone or pyramid	=	(Perimeter of base + perimeter of top) × ½ slant height.

WILKINSON PRODUCTS COMPANY

3987 Chevy Chase Drive, Pasadena 3, California

WILKINSON LINE LOCATOR

An electronic instrument for locating, tracing and indicating depth of any sub surface metallic structure —transmission and distributing pipe lines, cables, etc.



Our instrument cases are designed for heavy field use, being made of long grain three-quarter inch seasoned wood with mortised corners.

Automatic shut off prevents battery depletion when not in use.

All circuitry is completely enclosed in separate compartments but is easily accessible. This provision protects the heart of the instrument.

The loops are built into and are an integral part of the case frames. They are protected against moisture, vibration and shock by special cement.

The circuitry and component arrangement is designed to expedite servicing of the instrument when that is needed.

The latest type miniature tubes are used together with regular flashlight batteries. All tubes and batteries are standard stock items.

This instrument can be used inductively and conductively. It can be operated with both units assembled on the handle or separated.

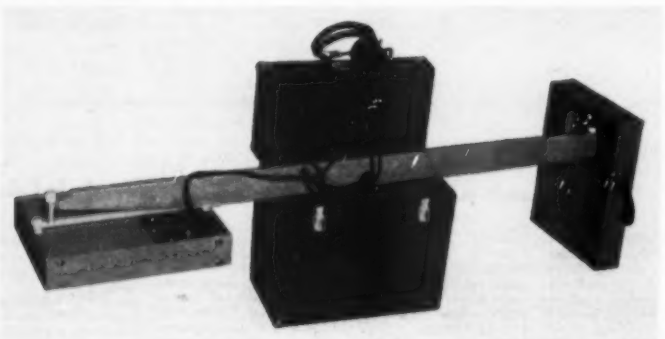
A depth gauge mounted on the receiver enables the operator to determine the depth of lines with accuracy.

A powerful transmitter provides sufficient output for the most difficult jobs.

Continuous engineering study has made this instrument especially stable and free from the usual misalignment trouble.

A substantial carrying case, with separate compartment for head phones, etc., is obtainable to protect the instrument.

Here Is the Complete Wilkinson Line Locator, showing Receiver, Transmitter, Connecting and Drop Handle, Head Phones, and Direct Cable



FURTHER PARTICULARS UPON APPLICATION

Distributors in Principal Cities

ELECTRONIC EQUIPMENT FOR LOCATING BURIED PIPES AND HIDDEN LEAKS

By HAROLD BERNARD

Graduate Student, Sanitary Engineering, University of Illinois, Urbana, Ill.

WITH cost-indices skyrocketing, the water works operator must find more means of economizing in order to offset increases in the cost of transmitting water. Economy can be realized by eliminating as much of the unaccounted-for water as is feasible. Unaccounted-for water, the difference between the volume of water from the water works and the volume reaching the consumer, includes both under-registration of meters and leakage from pipes. This paper will deal with the second factor, leakage and the detection of leaks and location of buried pipes.

Determining Leakage

One method used to determine the presence of excessive leakage is to check the rate of consumption between the hours of 1 and 5 A.M. With a knowledge of the industrial demands during that time interval and a comparison with the average daily pumpage, an indication of the amount of leakage may be obtaineed. R. D. McGill[1] stipulates that without industrial usage, the night rate of consumption should be approximately 25-30 per cent of the average daily rate. In the "Water Works Manual" of the American Water Works Assn., it is suggested that an upper limit for allowable leakage be 250 gal. per 24 hr. per in. of pipe diameter per mi. If a community is fully metered, the difference between the metered consumption and the volume pumped from the water works will indicate the presence of excessive leakage. Generally, 15 per cent of unaccounted-for water is considered a reasonable figure for leakage where all the water supply into the system and all services are metered[2].

Leakage Survey

If excessive leakage exists in the distribution system, a survey is made to locate the area in which this condition exists. After dividing the area into sections, the site of the leak may be sought by the following methods[3]:

1. With a Sounding Rod—In the sounding rod method, a rod is lowered into the ground in search of wet earth which is an indication of leakage. The process is repeated until the leak is located.
2. By Hydraulic Grade Line—By obtaining the water pressure at several points along the pipe and drawing the hydraulic grade line for the pressure, the leak is found to lie at the intersection of the grade line with the pipe.
3. By Water Hammer—By suddenly closing a valve in the pipe which is suspected to contain the leak, and recording the period between increases in pressure caused by the water hammer, the distance from the valve to the leak can be determined by substitution in the formula:

$$D = TV/2$$

Where D is the distance from the valve to the break in feet
T equals the time of return of the pressure wave in seconds
V is the velocity of the pressure wave in fps.

4. By Coloring Matter—If a dye is placed in the pipe, the site of the leak may be determined by observing the point of emergence of the colored water.
5. By Quickly Filling a Badly Leaking Pipe—When a pipe drains rapidly because of a bad break, the distance to the leak can be obtained by measuring the volume of water necessary to quickly fill the pipe and dividing that figure by the pipe area.
6. By Mechanical Amplification of Noise from a Leak—Since water escaping from a leak emits a sound, an amplifier can determine the site of the leak by locating the maximum intensity of the sound.

Electronic Pipe Finding

With the exception of locating the point of leakage with a sounding rod, all the methods indicated above, first require finding the pipe containing the leak. In many instances there are no records of the location of the pipe and its discovery must be left to chance or to electronic methods. An instrument which can be used to locate both the pipe and leak is an electronic detector especially designed for this purpose. The apparatus consists of a transmitter which emits electromagnetic waves that are induced in the earth. Any pipe in the field of the waves will act as a path of the return current and will radiate a field envelope[4] that can be received by an appropriate detector, as shown in Fig. 1. If the detector is in a plane perpendicular to the field, the ensuing signal obtained will be at a maximum. This phenomenon is used to locate the pipe.

The transmitter and receiver are separated by at least 30 feet to prevent coupling directly through the air, and the operators advance across the pavement in search of the buried pipe. When there is no metal introduced between the two units, the sound heard on the detector is low and steady. As a metallic object becomes interposed between the two units, the sound suddenly increases to a maximum. The line between the centers of the two units establishes the direction of the buried pipe. The site of the leak can then be detected.

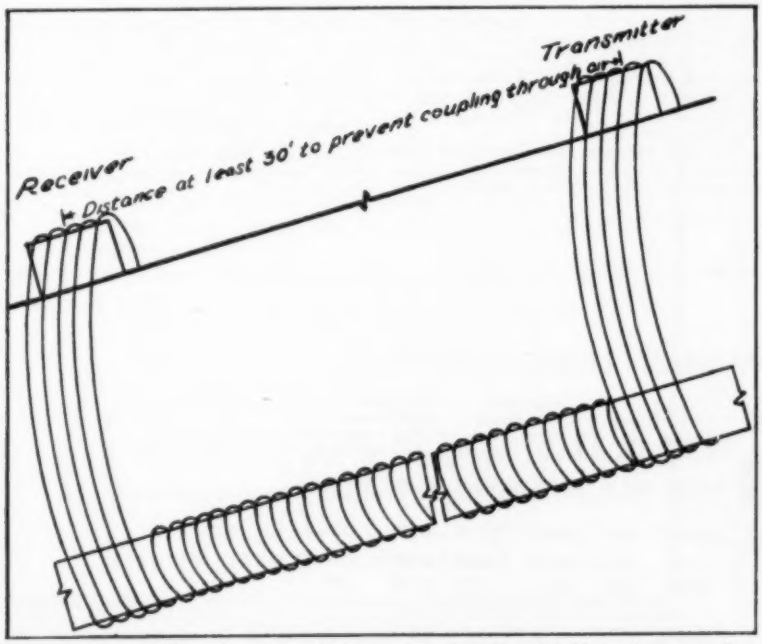


Fig. 1—Sketch illustrating induced electromagnetic field and field envelope around pipe

Leak Detection

As a fluid under pressure escapes through an irregular orifice, such as a break caused by structural failure, vibrations are emitted which travel along the pipe for considerable distances. An instrument tuned to the same frequency as the vibrations can pick them up, and subsequent amplification of the sound will identify the leak.

The pipe-finding apparatus can be modified to detect the leak vibrations by connecting a sensitive microphone to the amplifier as indicated by the manufacturer. The microphone is placed on a pick-up plate which is set on the ground at certain intervals, and the intensity of the resulting sounds compared. At the point of maximum intensity the instrument is directly above the leak.

If the vibrations of the leak cannot be detected as described, another method must

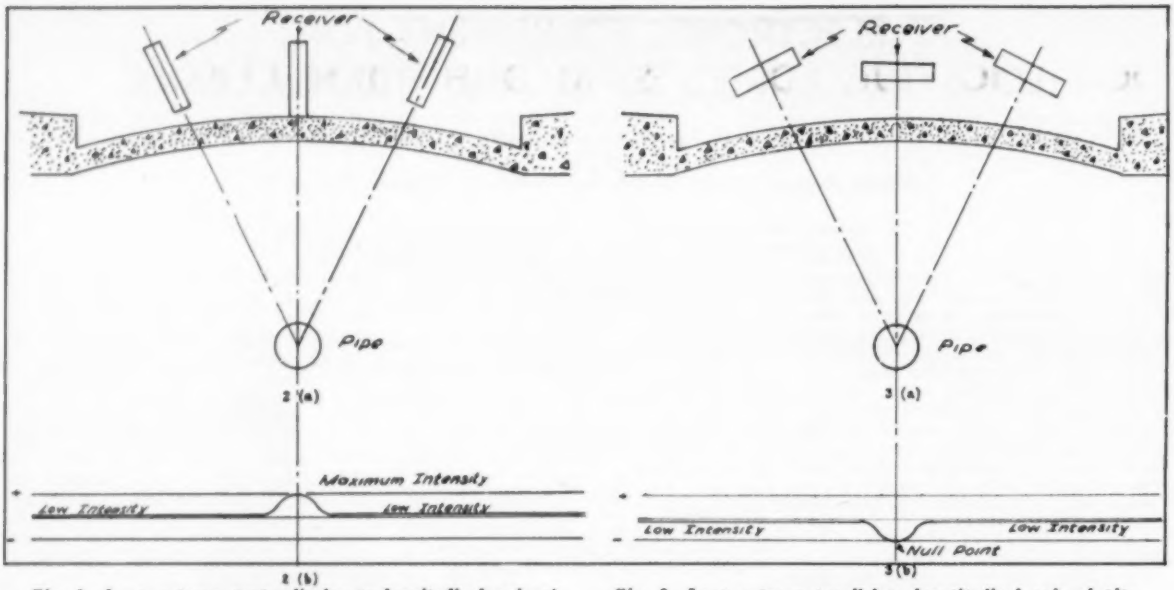


Fig. 2—Loop antenna perpendicular to longitudinal axis of pipe induces maximum current in pipe (Characteristics of maximum signal, below)

Fig. 3—Loop antenna parallel to longtitudinal axis of pipe results in null signal (Characteristics of null signal, below)

be used in which the microphone is placed in contact with the pipe. This method is based on the fact that the intensity of sound is 100 times stronger along a pipe than through the ground. The pick-up plate is placed on those hydrants, valves, and meters which are believed to be in the vicinity of the leak, and the intensity of the sound determined. The leak lies between the two readings which have the greatest intensities.

Should the leak still not be located, contact holes must be drilled and a rod lowered until it comes in contact with the pipe. The microphone is then placed on the rod and the intensity of the sound obtained. The sound is followed in the direction of increased intensity until a maximum is obtained indicating the point of leakage.

Pipe Locating

To locate the center-line of a pipe, two methods may be used, the maximum intensity method as shown in Fig. 2, or the minimum intensity method as illustrated in Fig. 3. The latter insures a greater degree of accuracy than the maximum response method. No signal is heard when the plane of the antenna is exactly parallel to the longitudinal axis of the pipe. When the null signal position of the detector is found, the pipe lies directly below the center-line of the antenna. Use of this method will give the position of the pipe within a space less than the diameter of the pipe.

If it is desired to locate the depth of the pipe below the surface of the ground, the pipe-locating apparatus is again used in the null position, but the loop antenna is held at an angle of 45° with the horizontal. The receiver is moved perpendicularly away from the pipe until the null position is obtained. This arrangement forms an isosceles right triangle with the detector, transmitter and pipe. The depth of the pipe below the surface of the earth will be equal to the distance between the center line of the pipe and the center line of the receiver minus the distance of the center line of the receiver to the surface of the pavement. This method locates the depth of pipe below the surface to within nine inches.

The leak detecting unit should be light in weight, have few controls, and have a microphone and headphone which are responsive to the full range of vibrations of leaks, i.e., 1,000 to 10,000 cycles. The apparatus should also include a filter which will exclude all sounds and noises not originating from the leak, and it should have a case that is an effective shield against extraneous electric fields.

Because of the savings that can be realized through a decrease in the number of man-hours consumed in locating buried pipe, and through virtual elimination of conjecture in finding and repairing a leak, electronic apparatus for pipe and leak location definitely should be part of the standard equipment of every water works maintenance department.

References

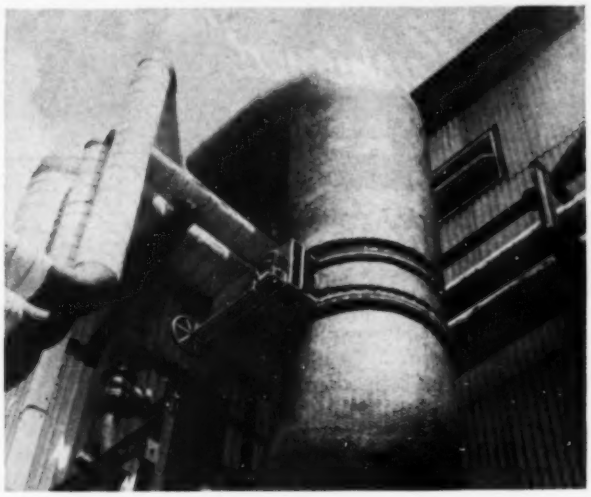
1. McGill, R. D., "Diagnosing Water System Defects," Jour. A.W.W.A., 41:189, Mar. 1949.
2. "Locating Leaks," Water Wks. Engr., 102: 419, May 1949.
3. Babbitt, H. E., and Doland, J. J., *Water Supply Engineering*, McGraw-Hill Book Co. Inc., N.Y., 4th Ed.
4. David, H., "Electronic Pipe Locators and Leak Detectors," Oil and Gas Jour., 46, p. 75, Jan. 15, 1948.

HOW MUCH LEAKS COST YOU

SIZE OF OPENING	AIR 100 lbs. Pressure		GASOLINE 15 Lbs. Pressure		WATER 40 Lbs. Pressure	
	Cu. Ft. Wasted Per Month	Cost at 10c Per M	Gal. Wasted Per Month	Cost at 4c Per Gal.	Gal. Wasted Per Month	Cost at 15½c Per M
3/16"	9,878,200	$987.82	423,000	$16,920.00	682,400	$106.00
¼"	4,448,800	444.96	188,000	7,520.00	307,700	48.00
⅛"	1,114,560	111.46	47,100	1,884.00	76,900	12.00
1/16"	278,640	27.86	11,800	472.00	19,200	3.00

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



R-S VALVES OPERATE EASILY

Above or Below Floor Level

Because of their comparative light weight and minimum space requirements, R-S Valves are particularly well adapted for installation at considerable heights above the floor level. In such positions they are usually operated manually by chainlever, chainwheel, extended reach rod or controlled automatically.

Where the valve must be installed in an inaccessible position below the floor level, a floor stand is provided. Control is just as quick and uniform as in those installations where the handwheel is mounted directly on the valve shaft.

Simplicity of design, the wide range of application and ease of operation indicate the high order of metallurgical and mechanical engineering that is embodied in every R-S Valve.

Consult your local R-S Valve Engineers, or write direct.

R-S PRODUCTS CORPORATION
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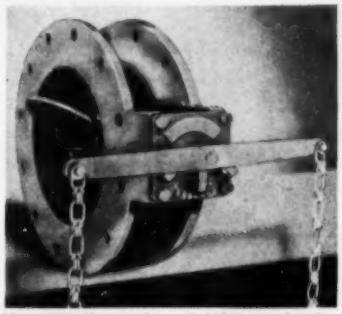
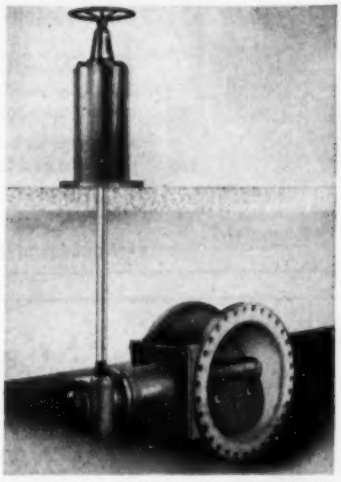
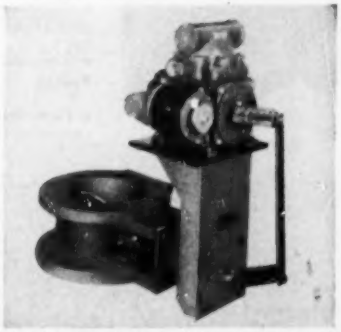


No. 688—Heavy duty chainlever valve for quick opening or closing in elevated and inaccessible locations. R-S Valves are used to control and shut-off the volume and pressure of nearly all materials in the temperature range from minus 300° to plus 2000° F. 2 to 2500 psig.



No. 788—Heavy duty valve equipped with rubber seat, totally enclosed gear reduction drive, extended shaft and floor stand. Positive shut-off is obtained up to 125 psig with rubber seated valves and commercially tight shut-off to even higher pressures with a babbitted seat.



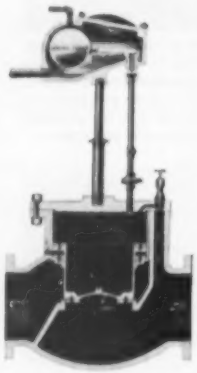
No. 839—8-inch heavy duty valve equipped with 125-pound flanges, 18-8 shafts, bronze bushings and a throttling type motor operator for the control of low pressure air.

NO AUTOMATIC MOVING PART CONTACTS

GOLDEN ANDERSON

AUTOMATIC "Cushioned" VALVES

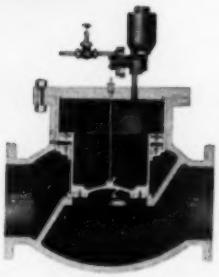
DESIGNED



Bulletin W-5

"Cushioned"
COLD WATER FLOAT VALVE

- High Pressure—for automatically maintaining a uniform water level in tanks, standpipes, reservoirs, railroad track pans, etc.
- Low Pressure—for automatically maintaining a sensitive water level control in mixing chambers, coagulating basins, etc.
- Air and water cushioning assure smooth operation and long life.
- For 150# WP and 250# WP. Sizes ½" to 36".
- Available in globe or angle body design.



"Cushioned"
SOLENOID-OPERATED ELECTRIC WATER SERVICE VALVE

- For any remote control application.
- Normally open or normally closed operating sequence.
- Air and water cushioning prevents shock or hammer and permits smooth operation at all times.
- Available in globe or angle body design.
- Sizes 2" to 36" for pressures 150 to 250 psi.

Bulletin W-7

Bulletin W-3

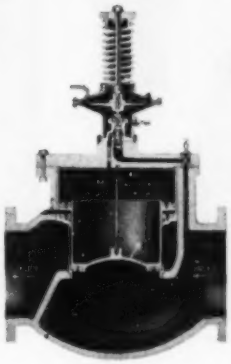
"Cushioned"
WATER PRESSURE REDUCING VALVE

- For automatically maintaining a uniform outlet pressure, despite variable inlet pressure.
- Opening and closing is cushioned to prevent water hammer and shock.
- Available in globe or angle body design.
- Furnished in sizes 3" to 36" for pressures 150 to 250 psi.

New technical bulletins describing the features and operating advantages of these specialty valves—gladly sent on request.

A CORROSIVE PART DURING OPERATION

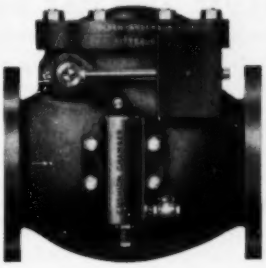
AND CONSTRUCTED ESPECIALLY FOR MUNICIPAL WATER WORKS SYSTEMS



"Cushioned" ALTITUDE CONTROL VALVE

- Maintains water level control within ranges of 3" to 12" for elevated tanks, standpipes or reservoirs.
- Available with electrical attachment to permit emergency closing from remote push-button control station.
- Inherent air and water cushioning prevents any water surges or shock in operation.
- Furnished in sizes 2" to 36" for pressures 150 psi. to 250 psi.

Bulletin W-4



"Cushioned" SWING CHECK VALVE

- Usually installed on pump discharge line and automatically prevents back flow into pump.
- Rapid closure when pump is shut down.
- Can be installed either horizontally or vertically.
- Especially designed with cushion chamber on side of body to prevent any slapping or banging against seat on closing.
- Available in sizes 3" to 36" for pressures 150 psi. to 250 psi.

Bulletin W-1

"Cushioned" SURGE RELIEF VALVE

- To protect water lines against excessive surges in the system.
- Automatically opens when inlet pressure exceeds adjustment of the pilot.
- Patented double cushioning design prevents all slam or hammer.
- Available in globe or angle body pattern.
- Regularly furnished in sizes 2½" to 16" for pressures 125 psi. to 400 psi.

Bulletin W-2

GOLDEN ANDERSON Valve Specialty Company

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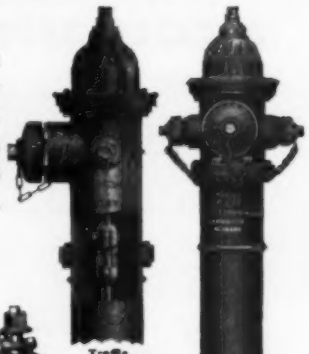
M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

The letters M & H are the sign of quality on Valves, Hydrants and Pipe Line accessories. High quality materials, simplicity of design and expert workmanship have established for M & H enviable reputation for dependable service in the water works and sewage fields and for industrial uses. M & H products are modern in design, with many exclusive M & H features.



M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc, parallel seat, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 36". Low Pressure Valves and Square Bottom Valves are an established part of the M & H line.

M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard or traffic models. Hydrants with 5¼" and 6¼" valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston and A.W.W.A. Hydrants with 4¼" and 4½" valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

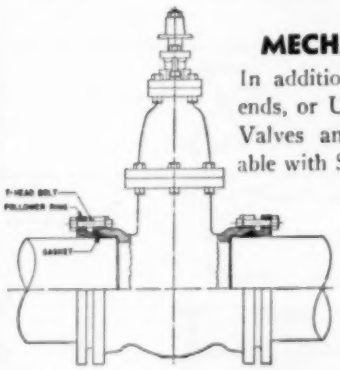
FILTER PLANTS & SEWAGE PLANTS

Hydraulically and electrically operated M & H Valves are used in sewage treatment plants, water works, filter plants, etc., to save time and labor since these valves can be operated by remote control for quick, easy closing or opening. They are also used as emergency valves to admit higher water pressures into the mains in case of fire. Sizes 2" to 36" A.W.W.A.

M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.

MECHANICAL JOINTS

In addition to hub ends, flanged ends, or Universal joints, M & H Valves and Hydrants are available with Standardized Mechanical Joint ends for use with standardized mechanical joint cast iron pipe as adopted by the Cast Iron Pipe Industry.



FIRE PROTECTION

M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

M & H PRODUCTS INCLUDE:

WALL CASTINGS	FLANGED FITTINGS	TAPPING SLEEVES AND VALVES
CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	B & S FITTINGS	FLANGE AND FLARE FITTINGS
	CUTTING-IN TEES	

VALVE AND HYDRANT MAINTENANCE*

By HOWARD W. NIEMEYER

Supt. of Distr., Indianapolis Water Co., Indianapolis, Ind.

CONSUMER dependence on an uninterrupted public water supply has grown almost beyond belief within the past two decades or so. Mechanical refrigeration, air conditioning, water-cooled industrial machines and other modern uses are creating such a continuity of essential demands that there is no longer a satisfactory or convenient time to shut off water service. Simultaneously, public tolerance for interruptions even in normal domestic service seems to be disappearing. This demand for a higher standard of service will force the plant operator to give more and more consideration to valves and hydrants.

Systems with inadequate valving will require the installation of additional main-line valves to minimize the areas of service interruptions which cannot be avoided. Unvalved hydrant leads, particularly in critical areas, will need valving to eliminate main shutouts during repairs. More thought will have to be given to the selection of the type of valves to be installed in large feeder mains for operation against unbalanced pressure. Particular attention must be paid to the design and structure of valves, to insure their endurance for the life of the pipeline so that they themselves will not be a cause for service interruptions to effect their repair or replacement. A preventive maintenance program for valves and hydrants, which has always been good operating practice, has become a must in perpetuating their readiness to serve.

It is unfortunate that valves and hydrants are not self-sustaining. The infrequency of their use may lead to the false assumption that they are not subject to wear and therefore remain in good operating condition without attention. The converse is more likely to be true, however, in that lack of use may be more detrimental than frequent operation. There are numerous forces at work which can cripple or destroy their usefulness for the purpose for which they were installed.

Corrosion

Probably the most serious distribution system problem today is corrosion. One phase of this problem has resulted from the promiscuous use of unprotected dissimilar metals in the structure of system components. Cast iron and bronze have long been the common metals used for water works materials. Separately they have an excellent record of endurance, but, suspended together in a solution, they produce galvanic corrosion. The rate and effect of this corrosive action in valves and hydrants will depend on their design and on the mineral content of the water, but it is always detrimental. Until such time as this problem is fully recognized and solved in either metal or structure design, the plant operator's difficulties will continue. It may be noted that galvanizing of the iron parts has been tried with some degree of success, but experience with this type of protection is insufficient to determine its long-range effectiveness.

In any corrosive action, there is a loss of metal, which results in a weakening of the affected part. If it is a working part subject to operating strain, progressive corrosion can eventually lead to failure. Equally as serious in valves are the products of corrosion, which form on the surfaces of moving parts and reduce or eliminate entirely the essential clearances needed for their freedom of movement. Periodic operation of valves will break off the corrosion deposit and help maintain the required clearances. Valves that have not been used for many years may be found to be entirely inoperative, because corrosion has swelled and then welded the moving parts into an unmovable, oversize mass.

Corrosion in hydrants does not exist in the same degree as in valves since the moving parts normally remain relatively dry. This situation changes, however, if the hydrants are set in an area of ground water that is sufficiently high to submerge their lower operating parts. Then corrosion can make their condition deteriorate enough to cause failure.

The stuffing-box gland of valves and hydrants is another source of difficulties presenting maintenance requirements. Corrosion that is primarily galvanic also takes place at this point and fills the clearance space about the stem with deposits. The most serious effect of this action is the increase in torque required to operate the affected valve and hydrant. Periodic operation will tend to work the deposit out of the gland and keep the operating stem moving freely, while neglect will allow the deposit to grow and harden until the stem becomes tightly wedged in the gland.

Of course, periodic operation of the valves and hydrants will cause a disturbance in the packing material in the stuffing gland. If this material has lost its resiliency, the gland will start leaking. This condition is not a problem in hydrants since they can readily be repacked, and it does not become a problem in valves until they leak continuously with the stem collar seated against its socket. A valve that leaks only during its operating cycle is a fault which is not serious enough to warrant the expense of the pavement cutting necessary to install new packing. Packing failures are sufficiently common, however, to require careful selection of the material to be used. The most satisfactory packing will be one that is noncorrosive, has permanent lubricating qualities, will not dry out and will seal with a minimum clamping pressure. Experience indicates that only a few types of packing will meet all of these requirements.

Street Improvement

High on the list of causes of valve and hydrant difficulties is street improvement and maintenance work. Experience would indicate that street contractors and city maintenance crews do not share the plant operator's view of the importance of keeping the utility's appurtenances in readiness for emergencies. Apparently they consider valve boxes and vaults as objects to be destroyed or buried, and fire hydrants are merely bumping blocks for bulldozers and road graders. Rigid inspection of all known street improvement jobs is necessary to see that all valve boxes and vaults are in position and properly graded. It is helpful to make a survey in advance of the construction work and to drive reference stakes along property lines to mark the location of all valves. It is also good practice to install new packing in the valves and to perform any other needed maintenance before a new pavement surface is put in place. If additional valving is advisable in the area of the street improvement, it can be installed without paying the high cost of pavement cutting and repairing. In addition, hydrants may have to be relocated to suit changes in curbings.

Street improvement or major resurfacing projects can be watched to guard against damage to the distribution system parts, as the utility will have advance notice of such work. It is the street maintenance crews, who cannot be followed, that are responsible for the large number of valve boxes covered or destroyed each year. Asphalt patching crews can be depended upon to cover with bituminous material any valve box in the area of a street repair. Road graders used on the unimproved streets will regularly break or tear up valve boxes without such damage being reported to the utility. The time lost by the utility in emergencies because of these artificially created difficulties can be quite serious.

Homeowners, in regrading their lawns, may either extend a terrace or cut the grade around a hydrant located at the property line. In the former situation, the hydrant nozzles may be so close to the ground as to interfere with the connection of a fire hose. In the latter, the hydrant is left standing high in the air, an unsightly object, and frost may penetrate to the base because of insufficient earth cover. Owners also have built fencing so close to a hydrant that it prevents the spinning of the operating wrench. These home projects which create hydrant hazards are seldom reported.

Effects of Traffic

Traffic can result in unfavorable conditions. Valve boxes located in an unstable road bed may be shifted by traffic loads so that the operating key cannot be engaged with the valve key nut. Boxes may be tilted so that a protruding edge becomes a hazard to pedestrian traffic. Vaults may become weakened, leading to the danger of a cave-in under traffic.

Hydrants are also traffic casualties and can be damaged in unreported collisions so as to render them useless to the fire department. They may be knocked out of alignment, the nozzle treads injured, the nozzles knocked loose in their sockets, or the base assembly damaged by an impact. In one hydrant, a test showed the barrel to have been broken in two, yet the hydrant appeared to be in good condition. If such damage is not reported to the utility, it must be found by regular inspection, or the faults may continue to exist until a hydrant is needed for fire fighting.

In replacing collision-broken hydrants, it is well to inspect their setting to determine if they need be relocated to a less vulnerable position. Hydrants should be

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set a safe distance from a curb and as far from street intersections as possible. The breakoff type of hydrant has many advantages and merits careful consideration. A collision with this type does not result in an emergency, and, since the broken section is readily discernible, a prompt report will probably be made to the utility. Furthermore, repairs can be made without shutting off the main.

Freezing Climates

In freezing climates, where hydrants must drain for wintertime service, tree roots are always a source of difficulty. The importance of keeping the drain ports open is obvious. It is a good practice during the winter to check all hydrants as soon as possible after their use by the fire department. Nondraining hydrants should immediately be drained with a handpump to keep them in readiness for additional service until a maintenance crew can open the drain ports. Clogged drains can often be opened with compressed air to avoid an excavation job. The installation of a piece of copper wire or tubing in the hydrant drainage bed to stop root growth has been suggested.

Much damage can result to valves and hydrants through their use by inexperienced or unauthorized persons. Valves may be left partially or completely closed. Hydrants may be damaged or left partly open. Hydrant caps may be left loose or not replaced at all. To safeguard against these irregularities, all valve and hydrant operations should be strictly confined to the distribution system maintenance division, and operation by any other plant personnel or by outsiders such as street contractors, construction workers or contractor main-laying personnel should be prohibited. Temporary hydrant connections occasionally required by outsiders should be furnished by the utility with the installation of a hand wheel valve on a hydrant nozzle, leaving the hydrant open for the duration of the use. Such hydrant operation should be reported to the fire department. This policy assures that full knowledge of all valve changes will be available to the division responsible for distribution system emergencies, and it limits all operations to experienced personnel.

An exception to the above policy will, of course, have to be made for the fire department and city street-flushing and sewer-cleaning crews. There should be a special effort to give these groups instruction in the proper use of hydrants. A sectional hydrant can be furnished by the utility for training purposes.

All instructions should particularly emphasize the importance of replacing all nozzle caps as tightly as possible. Failure to do so is an invitation to trouble from the younger generation.

Testing Programs

Ample illustrations have been given to prove the need for periodic inspection of valves and hydrants if they are to be maintained in a ready-to-serve condition. Should the many faults that can and do develop be left to accumulate over a period of years, the plant operator might find himself in a desperate situation when a real emergency arose. The frequency of periodic inspections varies, but generally a yearly interval is adopted. The hydrant testing program is preferably conducted during the fall since most faults develop in the spring and summer. Autumn testing also allows conditioning of the hydrants ahead of winter service requirements. There is no particular seasonal advantage for valve testing.

Complete and accurate maps and records of the distribution system are essential in establishing the testing programs. Simply stated, a valve cannot be tested if there is no record of its installation. Numerous water works publications have described map and record systems that are considered good practice. It is suggested that, in addition to the standard system records, it is worth while to have a permanent test report card for each valve and hydrant. Such a card carries a complete description of all physical data regarding each installation—make, size, type, location, measurements from reference points, date of installation, identification number and a test route number. In addition, the valve test card should show the type of setting (box or vault), the number of closing turns and the direction of turning, if any plant operator is so unfortunate as to have mixed directional valves in his system. A 5 × 8-in. card will allow enough horizontal lines for at least 30 test reports, using both sides. Vertical columns with headings of items to be reported will permit the testing personnel to use check marks, requiring only a minimum of writing. The cards should be filed in the office by route number and should be taken out in the field only in quantities sufficient for a day's work.

The use of test report cards has a number of advantages: Once an efficient testing route has been developed, it can be followed for all subsequent tests. There is less likelihood that any valves or hydrants will be missed. The testers carry with them, in convenient reference form, complete information regarding each installation, and also have the benefit of all past testing history, so that they are aware of any abnormal condition that may exist. A considerable saving in paper work results.

As previously mentioned, the existence of both left- and right-hand valves in a system is an unfortunate circumstance, particularly if there is an absence of maps and records which accurately specify the operating direction of each valve. It would appear that valve operations are confusing enough to warrant the conversion of all valve to a single operating direction.

The testing of valves and hydrants requires the operation of the devices through their entire cycle, as partial operation is insufficient to establish their true condition. The purpose of the inspection is to determine readiness to serve, which can be judged only from a complete test.

Minor Maintenance

During the test deficiencies other than faulty operation should be detected almost automatically, and certain items of minor maintenance should be performed as part of the testing program.

The hydrant work should include lubrication of the operating nut, tightening or replacement of the stuffing-gland packing as needed, greasing of the nozzle cap threads and calking of loose nozzles. Obstructions to the visibility of the hydrant and poor condition of paint should be noted in the test report. It is also suggested that, since travel time is a considerable item in the inspection cost, other types of surveys can be incorporated in the program at slight added expense. Little time is required for the testing crew to listen in on each hydrant with some type of mechanical or electronic leak detector. A pressure survey of the entire distribution system can be readily obtained by having the crew install a nozzle cap equipped with a pressure gage. Some utilities take a pitot measurement of each hydrant's delivery rate, while others have the testing crew flush all hydrant leads and some dead-end mains. Three men can test about 120 hydrants in an eight-hour day. The addition of a leak and pressure survey to the program will only reduce the number of hydrants tested in the same length of time to 100.

The maintenance work which can be incorporated in a valve testing program is rather limited because the valves are inaccessible unless installed in vaults. Stuffing-box packing can be replaced or tightened in vaulted valves, if required. Likewise, geared valves can be cleaned and lubricated as needed. Maintenance of buried valves during testing is limited to finding and adjusting the height of valve boxes in dirt streets and cleaning boxes of obstructions. Hard-turning valves and those which will close only partially should be worked until they operate freely. It has been found helpful in working a hydrant branch valve to open the hydrant sufficiently to secure a scouring velocity through the valve. Sometimes a scouring velocity can be obtained through main-line valves by closing off a section of main in back of the valve and opening a hydrant leading off this section. Even valves with kinks in the stem which allowed only partial closure have been worked until the valve operated freely through the kinked section. The operation of these faulty valves is considered an important part of the testing program. Each valve which can be conditioned in this manner eliminates a main shutoff, a street excavation and the need for opening the valve in order to make repairs.

Power Operation

In the author's opinion an adequate and satisfactory job of valve testing cannot be done manually. Even if all the valves were in perfect condition, the physical requirements for testing a system of any size would place a considerable strain on the personnel. It is not possible to operate faulty valves manually in the way previously discussed. Power operating equipment is available for such work and should have preference.

One method of power operation is the use of a compressor-driven air motor of low speed. This type has the advantage of reaching valves inaccessible to trucks, but there is a drawback in that the air motor must be held by the crew in opposition to the turning torque of the valve. As in manual testing, the valve turns must be counted and there is always a likelihood of error, particularly in operating large valves which require a great many turns.

Another method employs a truck-mounted operating head powered by a takeoff from the truck engine. The head can be mounted on the right-hand side so that valves near a street curb can be reached by the operator with the truck going in the direction of traffic. With the right-hand mounting, the revolution counter, which is part of the equipment, is installed on the truck instrument panel, enabling the testing personnel to synchronize the flow of power with the registered position of the valve faces. Damage to valves is avoided by the use of multiple shear pins in the driving linkage, varied in number to suit the size of valve being tested. This type of power testing has made a hard job easy and has been used

with most satisfactory results for all sizes of valves, even down to 4 in. Excellent results have been obtained with it in conditioning valves.

The valve testing truck at Indianapolis, Ind., is equipped with a phone, and the testing crew has been given the assignment of making emergency and routine main shutouts. Tighter valve closures are being obtained than with manual operation, and the maintenance crews have drier repair jobs.

There are intangible benefits to be derived from the periodic testing of valves in addition to those resulting from the location and repair of faults. The valve operating crews become thoroughly acquainted with the distribution system, its shutoff sections, the location of valves and their operating characteristics. With this experience, they can meet an emergency situation with precision, and valuable time is saved when it is needed most.

Valve and hydrant defects reported by the testing crew should be repaired as quickly as possible, the inoperative ones being given initial preference.

Hydrant painting is not connected with the testing program but is a maintenance job that should also be performed on an established schedule. The selection of the color to be used should be based entirely on visibility, particularly at night. The frequency of painting will be determined by the durability of the paint and the exposure of the hydrant to grime and dirt. Some utilities paint the hydrant bonnets and caps according to a color code which denotes the delivery capacity of each hydrant. This practice is an aid to the fire department.

The National Board of Fire Underwriters has established minimum standards for the installation of valves and hydrants needed to maintain adequate fire protection service. In order to satisfy these recommended standards and at the same time meet the high level of general service required by modern public water supply uses, valves and hydrants must be given proper consideration.

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2.60	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8.22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171 11
24	10.39	77	33.35	130	56 31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103 53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13.42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19 05	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19 49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42 88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66 27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112 62	1000	433.18
49	21.22	102	44.18	155	67 14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44 61	156	67.67	209	90.53	262	113 49	2000	866.3
51	22.09	104	45.05	157	68 0	210	90 96	270	116.96	3000	1299.5
52	22.52	105	45 48	158	68 43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

THEORETICAL HORSEPOWER

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

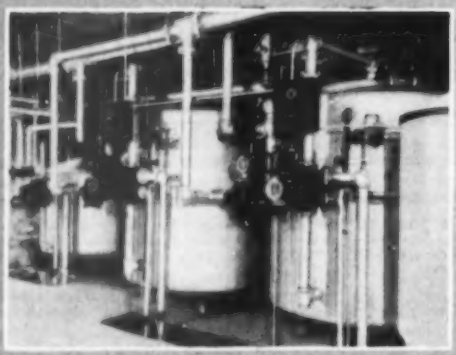
HEAD IN FEET

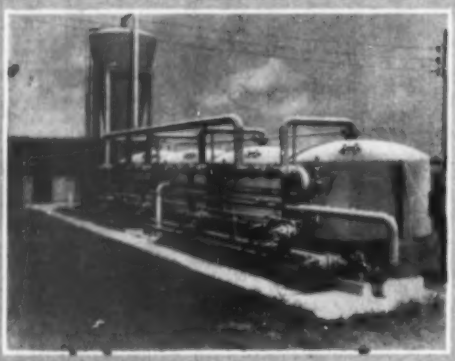
Gallons per minute — Ft.	10	15	20	25	30	35	40	45	50	60	75	90	100
10	.03	.04	.05	.06	.08	.09	.10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	.47	.57	.63
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	.26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	.34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	.85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	.63	.76	.88	1.01	1.14	1.26	1.51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.16	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2 52	3.03	3.53	4.04	4.55	5.05	6 06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6 31	7 58	9.47	11.36	12.63
550	1.39	2 08	2.78	3.47	4.17	4.86	5 56	6.26	6.94	8.33	10.42	12 50	13.89
600	1.52	2 28	3.03	3.79	4.55	5.30	6 06	6 82	7.58	9.09	11 36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2 66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10 60	13 26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11 36	14 20	17.04	18.94
800	2 02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10 10	12.12	15.15	18 18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19 32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10 10	11.36	12.63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10 10	12.63	15.15	17.67	20.20	22.72	25.25	30 30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30 30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

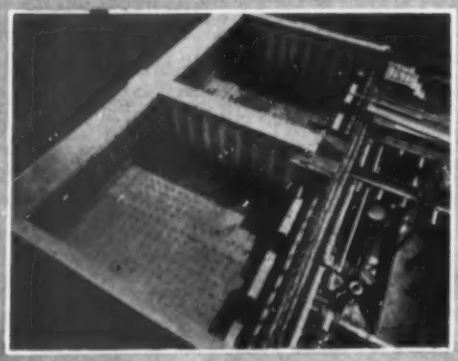
NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{3960 \times \text{Effy. of the pump}}$$

4 STEPS TO BETTER WATER







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WATER CONDITIONING HEADQUARTERS FOR 40 YEARS

HARDNESS REDUCTION VS. REMOVAL

A Critical Evaluation

By T. E. LARSON

Head of Chemistry Sub-Division,
Illinois State Water Survey,
Urbana, Ill.

IT IS universally recognized that municipally softened water is wholeheartedly approved by the consumers where such water is provided. It is a fact that such water can be further improved for specific purposes. But even zero hardness water is not ideal, and other types or forms of treatment are required. The purpose and desirability of providing municipally softened water are economically justified and desirable, just as are the purpose, desirability and even the need for further "polishing up" or "finishing" treatments for specific applications of such water.

The water treatment industry still has much to do in order to provide an acceptable product to the major percentage of the population. Municipal hardness *reduction*, home service and home owned hardness *removal*, and synthetic as well as soap detergents are here to stay. No one of these practices will replace another, but all supplement each other in general water treatment. Recognizing this fact, we may orient our thinking on water treatment for the individual by summarizing some data regarding water consumption in the United States and providing particular reference to water treatment in Illinois.

United States

In 1945 there were 15,400 water works plants supplying approximately 94.3 million persons, or about 70 per cent of the 1940 population, with an average of 127 gallons per capita per day. Currently it may be estimated that there are 16,500 plants in the United States.

A census in 1945 also indicated that there were some 665 municipal softening plants supplying 12 million people, or approximately 9 per cent of the total population of 1940. Currently, it has been estimated that some 15 million persons are provided with municipally softened water, or approximately 10 per cent of the 1950 population.

In addition, it has also been estimated that there now are approximately one million privately owned softeners supplying approximately 3.6 million persons, or 2.3 per cent of the total population, and 900,000 soft water services supplying 2.1 per cent of the population. Therefore, if these percentages may be totaled, it would appear that some 14.4 per cent of the population is provided with soft water by treatment; or on the basis that treatment is provided only in hard water areas, 20 per cent of the 112.5 million people living in these areas are provided with soft water treatment.

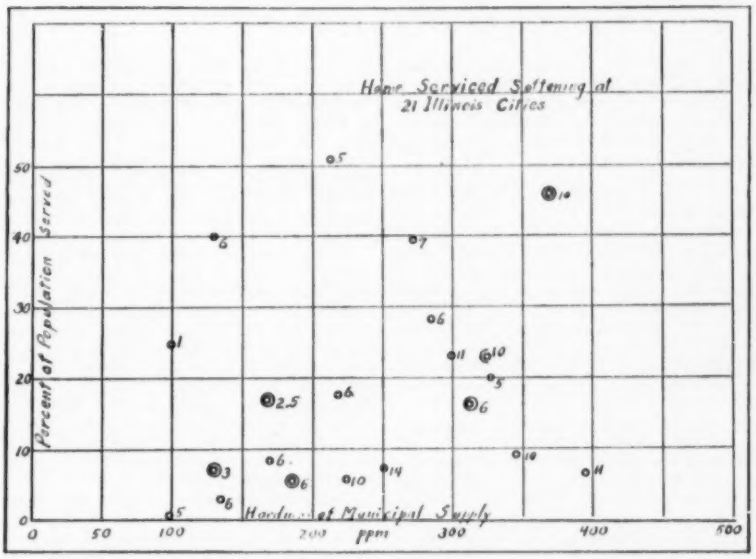

Fig. 1—Water softening by home service operators in 21 Illinois cities. Data show no evident relation between hardness and population served.

Illinois

Illinois is classed as a hard water state. A recent publication, Circular No. 31, issued by the Illinois State Water Survey and titled "Mineral Content of Public Groundwater Supplies in Illinois" has shown that 88.7 per cent of these groundwater supplies have a hardness greater than 200 parts per million. (Table I). Only17 per cent of these

Table I

MUNICIPALLY SOFTENED HARD WATER SUPPLIES IN ILLINOIS

Hardness	Percent of 532 Supplies	Percent of These Supplies Softened
201 ppm. or more	88.7	17.0
251 ppm. or more	77.8	17.4
301 ppm. or more	60.2	20.2
326 ppm. or more	48.7	22.4
351 ppm. or more	41.6	22.5
401 ppm. or more	27.0	25.2
501 ppm. or more	11.5	24.6

are municipally softened. A little less than 50 per cent of the supplies have a hardness greater than 325 ppm., and 22 per cent of these supplies are municipally softened. It is interesting to note that only 24.6 per cent of the 61 supplies which have a hardness greater than 500 ppm. are municipally softened.

No data are available on the extent of softening for *surface* water supplies. However, with the exception of supplies obtained from Lake Michigan, the median hardness for surface water supplies is approximately 300 ppm.

The extent to which the general public desires clear, soft water is perhaps no better exemplified than by the fact that $1.35 to $4.05 per thousand gallons is currently being paid for soft water service on supplies having 200 ppm. and 600 ppm. hardness, respectively. This cost is in addition to the cost of purchase of the particular municipal water of such quality as is provided. These costs for municipal water range from 35 cents to approximately $1.50 per thousand gallons and in no case is the water delivered with a hardness less than about 60 ppm.

A questionnaire sent to home service operators in Illinois showed, Fig. 1, that no operator provided service to more than 50 per cent of the population in the city served. Four operators, after ten years, provide service to less than 10 per cent of the population. The number of years in business are indicated numerically at each point in Fig. 1. The double circles represent operators who have no competition in their community. It appears that it makes little differ-

This paper is a revision of one presented by the author before a meeting of the National Assn. of Water Conditioning Equipment Manufacturers.

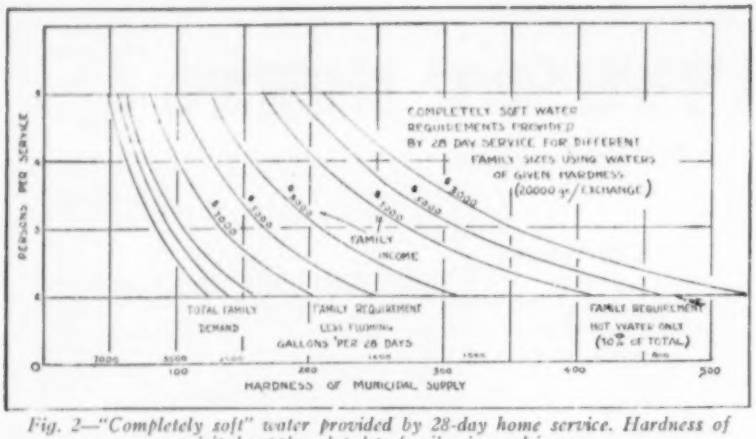

Fig. 2—"Completely soft" water provided by 28-day home service. Hardness of municipal supply related to family size and income.

ence whether the hardness of the city supply is 100 or 400 ppm., home serviced softening can be made desirable. No data were available on the funds used for increased capital expenditures and for advertising.

Residential Use

A recent publication[1] by Larson and Hudson of the Illinois State Water Survey staff has provided a detailed analysis of residential water use as compared with family income. These data on 15 Illinois cities of population ranging from 900 to 900,000 show a per capita residental use of 21 to 52 gallons per day for family net buying incomes of $2,000 to $7,500 per year respectively.

If complete sanitary facilities were available to the lower income residences, it was estimated that the $2,000 income residential use would be increased to 37 gallons per capita per day.

No correlations were found between residential use and size of community, water rates, pressure, use of meters, or quantity or quality of the water supply. The hardness of these supplies ranged from 125 to 313 ppm., and the iron content from 0.0 to 0.5 ppm.

These data should be of particular value in the general design of completely soft water service for full line installations as well as for hot water installations, but should be used with great caution for specific individual installations.

The quantity of "completely soft" water provided by 28 day service is shown in Fig. 2 for different family sizes and with different family incomes when provided with waters of specific hardness.

A family of 3 can obtain completely soft water for all its requirements if the city water has a hardness of 100 ppm. If 60 ppm., a family of 5 can be serviced. A family of 4 can be provided with its soft water requirements only when the hardness is 250 ppm. and only a family of 2 can obtain such service if the hardness is 450 ppm. With 40,000 grains per exchange, the values of hardness in Fig. 2 would be doubled.

Municipal Softening

It would be rather pointless to discuss in detail the cost of providing municipally softened water at this time, since this has very ably been indicated by L. R. Howson[2]. Suffice to say that his conclusions state: "Reduction in hardness down to 5 grains per gallon can most economically be made available to the greatest number through softening of the municipal supply, and for those who wish completely softened water, the individual softeners are the best solution." In addition, it might be pointed out that municipally softened water benefits those in the lower income bracket more than those in the middle or high income bracket since the net savings obtained thereby are less frequently supplemented or accomplished by the aid of home softeners.

This is borne out by the fact that a recent survey by one of the soft water service companies has indicated 27 per cent of the services are provided to high income families (6 per cent of the spending units, buying income greater than $7,000/yr.); 57 per cent of the services are provided to the middle income families (64 per cent of the spending units, buying income $2,000 to $7,000/yr.); and 16 per cent of the services are provided to the low income families (30 per cent of the spending units, buying income less than $2,000/yr.).

Only the misinformed can deny these conclusions and the fact that no water is ideal in quality for every purpose. It is for this reason that there are so many different "finishing" or "polishing up" treatments currently in use by industries, as well as by private consumers, for the many various purposes for which water is used.

It is indeed unfortunate that discussions on the relative merits of municipal softening and home-owned or home-serviced softening frequently are biased, and thereby prove to be harmful to the proponents of both sides.

A careful analysis of the overlapping factors indicate that each treatment supplements the other for the ultimate benefit of the user. Home softening finishes the job of providing a completely soft water which is started by municipal softening. Municipal softening (hardness *reduction*, if you please) provides more hardness reduction per householder's dollar than *any other* method and reduces the hardness to a point where the home-owned and home-service softeners (or hardness *removal* units) can handle more water for a lesser cost.

A strong educational program is in order to inform the home unit operators whether home-owned or home-serviced, of the very definite advantages of municipal softening. Likewise, an equally strong educational program should be established for the proponents of municipal softening to insure that their discussions indicate municipal softening *reduces substantially* but *does not eliminate* hardness.

It should be pointed out that municipal softening not only removes the major proportion of the ingredients which are responsible for hardness in the water supply but also removes color, odor, iron and manganese, all of which are of important nuisance value to the serviced soft water operators and to home owned softeners.

Corrosion Problem

It is entirely impractical to completely soften water on a municipal basis, since its resultant effect on the distribution system and the effect of the system on the quality of the water would thereby both be detrimental. For transportation and distribution municipally softened water can economically be made relatively non-corrosive, which is one thing that cannot at the present time be said for completely softened water. Municipal water (softened or not)

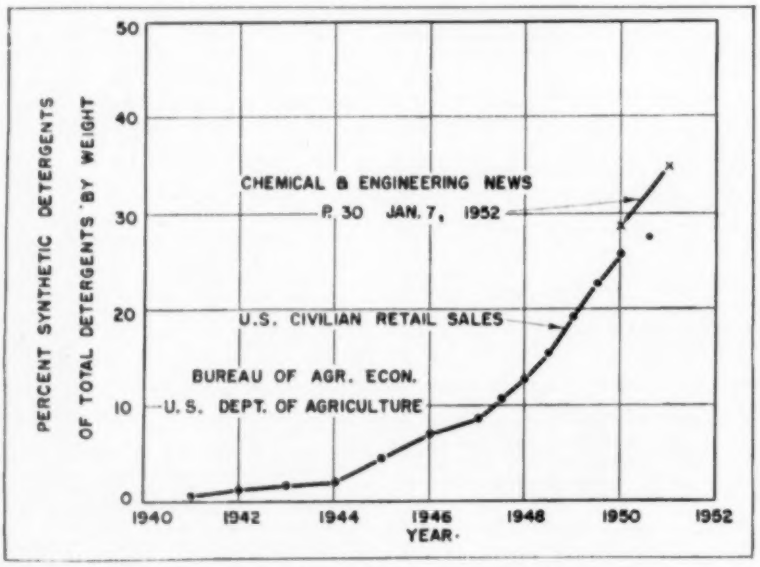
PERCENT SYNTHETIC DETERGENTS OF TOTAL DETERGENTS BY WEIGHT
CHEMICAL & ENGINEERING NEWS
P. 30 JAN. 7, 1952
U.S. CIVILIAN RETAIL SALES
BUREAU OF AGR. ECON.
U.S. DEPT. OF AGRICULTURE
YEAR

Fig. 3—Rate at which synthetic detergents displace soap.

is never made non-corrosive by complete softening. If relatively non-corrosive before complete softening, such treatment may cause the water to become corrosive (or less protective). If corrosive before complete softening, water will become no less corrosive but probably more corrosive (again less protective) by such treatment.

Proper municipal softening practically eliminates the tendency for water to form scale deposits. These deposits are responsible for burned spots in water heating where direct fire is applied on the opposite side of the metal. Complete softening removes all scale forming tendencies and also renders the water less protective.

Complete softening, therefore, presents a major problem—a problem which water works technicians have wrestled with for over 100 years. The problem has become more acute in recent years with the development and use of small high capacity water heaters. By and large, proper proportioning of hardness, alkalinity and pH offers the best general solution; but specific uses and after treatments frequently can destroy all efforts previously made by the "wholesale" distributor. It is significant that the National Association of Soft Water Service Operators is devoting particular attention to this problem from the standpoint of providing a non-corrosive water to the consumer as a service as well as reducing maintenance and replacement costs on their own equipment.

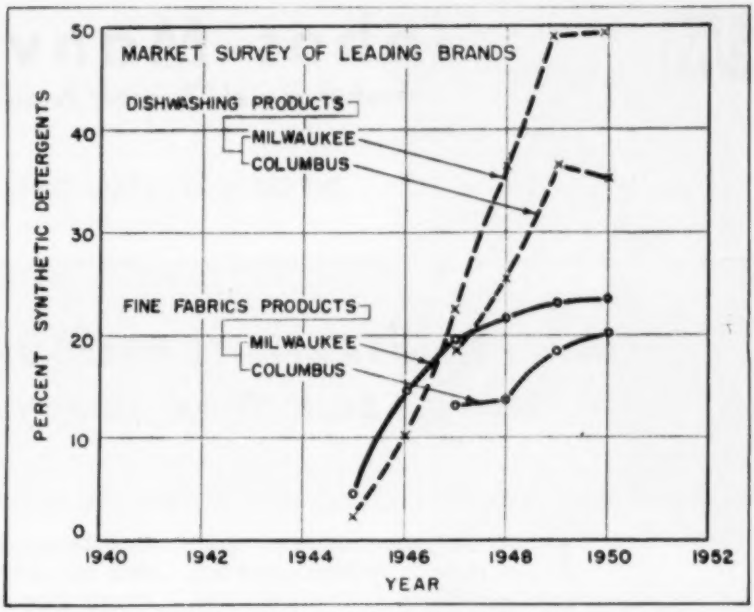

Fig. 4—Rate of household synthetic detergent utilization in two cities.

Soap and Synthetic Detergents

Although the majority of the objectionable constituents have been removed, municipally softened water obviously still leaves something to be desired when used for particular purposes. Additional "polishing up" treatment is advantageously provided for some purposes by use of soap or synthetic detergents with or without the use of serviced or home-owned softeners. By comparison, either soap or synthetic detergents may be of greater advantage for different water qualities and for specific purposes.

Even among the many synthetic detergents, some are better for specific purposes than others. No synthetic detergent has been found to be an improvement on the use of soap with completely soft water for the purpose of washing cottons and linens. Beauty shop operators are thoroughly sold on completely soft water, regardless of whether the shampoos are made from special soaps or synthetics. On the other hand, synthetic detergents have proven to be of particular value for washing woolens, nylons, silk, and, to a large extent, dishwashing even in hard water.

A word of caution may be of value at this point. In the study and interpretation of comparative test data on the effectiveness of soaps and synthetic detergents for various uses with various waters, particular attention must be given to the conditions of the test and the methods of evaluation of the results. For example, reliable authorities on detergency have long known that foam height is not a measure of detergency power. In recent years, secondary "experts" are also recognizing this fact and currently many of the consumers are becoming so educated. However, foaming ability is still, altogether too frequently, being cited as the criterion of relative detergency efficiency. The factors involved are so numerous that laboratory tests must be considered as indicative only under specific conditions and then only on the basis of end results on repeated representative washings.

An example of one factor of water composition lies in the alkalinity and pH of the water used. It is possible that a superior detergent for water of zero hardness, 50 ppm. alkalinity and pH 8.0 may not be superior for a water with zero hardness, 300 ppm. alkalinity and pH 8.0, and even less so if the latter water had a pH of 7.0. The acidic or neutralizing properties of free CO_2 and of sodium bicarbonate do not appear to be fully recognized in all of the laboratory tests now being reported.

The extent to which synthetic detergents will be further developed for specific applications is difficult to determine, since the industry is still in a growing stage. It is significant, however, that synthetics continue increasingly to displace soap in retail detergent sales. See Fig. 3. In 1951, 35 per cent of the retail sales of detergents on a pound basis were synthetic detergents.

On the other hand, a market survey[3] of leading brands of products sold for dishwashing and products sold for washing fine fabrics in Milwaukee and in Columbus, appears to show that synthetic market in these two cities has leveled off. See Fig. 4. However, it would be wise to reserve opinion until at least one more year of confirmatory data has been obtained. As a sidelight, it is interesting to note that 35 per cent of the detergents used for dishwashing in Columbus were synthetics, whereas in Milwaukee (where the hardness is 130 ppm., compared to 85 ppm. in Columbus) 50 per cent of the detergents used for dishwashing were synthetic.

General Futility of Cost Discussions

It would be possible to discuss extensively the many uses and specific treatments for utilizing each of the many possible qualities of water. It is rather pointless to discuss the economics of such treatment from a cost of chemicals standpoint, since the chemical cost for iron removal, for instance, is often zero and the chemical cost for making distilled water is often zero; and, omitting any consideration of investment in capital equipment and maintenance, the cost of iron removal is practically negligible, whereas the cost of distilled water may be as high as $90 per thousand gallons. And think of the bonanza of canned drinking water at 15 cents for a 10.5 ounce can—$1,830 per 1,000 gallons.

The important conclusion that can be drawn from these data is that *Service* and *Quality* of product are the keys to the purse strings controlled by the American housewife.

References

1. Larson, B. O. and Hudson, H. E., Jr. Residential Water Use and Family Income. *Journal A.W.W.A.* 43, 603 (1951).
2. Howson, L. R. Economics of Water Softening. *Journal A.W.W.A.* 43, 253 (1951).
3. McCutcheon, J. W. Soap and Sanitary Chemicals. 26, 85 (1950).

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Class (maximum recommended working pressure, psi)	Equivalent head, feet of water	Nominal inside diameter, in.						
		4	6	8	10	12	14	16
		Pounds per linear foot including coupling and rubber rings						
100	231	6.4	10.8	16.0	22.8	30.4	39.2	51.3
150	346	7.6	13.0	19.8	31.9	43.3	57.7	72.5

FUNDAMENTALS OF CORROSION AND ITS MITIGATION*

E. W. MOORE[1], W. H. SEARS[2], AND L. RUBIN[3]
NEWWA Committee on Corrosion

THE Committee to Report on Developments in our Knowledge of Corrosion and its Mitigation was established by the N.E.W.W.A. in 1942. The pressure of war activities on the membership of the Committee prevented any effective work during the subsequent years until July, 1948, when a meeting was held to determine its future course.

Further discussion led to the conclusion that the Committee might partially fulfill both objectives by adopting the following courses of action:

1. To prepare a basic report which would, insofar as possible, summarize present knowledge on corrosion.

2. Using this basic report as a point of departure, to examine critically the new developments in the field at such times as the Committee considers that sufficient evidence is at hand for examination and reporting.

The present report is submitted as the basic report of the Committee.

I. Definition of Corrosion

In order to carry on adequate studies of corrosion in the field of water supply, it is necessary that criteria be established that may be used to determine the existence and the extent of the problem. Since corrosion has to do with piping systems and water supplies, its existence is recognized by its effects on either or both. In general, the effects of corrosion on the water supply are manifested much sooner than the effects on the piping system. This report will deal primarily with the corrosion of the interior surfaces of piping and will not be concerned, except indirectly, with corrosion of the exterior surfaces due to contact with various types of soils or to other agencies.

1. **Effect on System—Destruction, Tuberculation, Clogging.** Corrosion consists primarily of the solution of the metal components of the piping system by the action of the various substances present in water. The continuous solvent action results in a weakening of the pipe structure, which eventually may manifest itself in many ways, such as

a. Leaks in service lines, mains, domestic piping
b. Leaks in domestic hot water boilers
c. Corrosion of water meter parts

Inspection of any piping that has developed a leak will reveal the solvent effect of corrosive action in the form of pitting, dezincification, or general reduction in pipe thickness.

Another evidence of corrosion is the occurrence of tuberculation in the piping. When certain metals, especially iron, go into solution in water, they tend to react with the basic substances and the dissolved oxygen in the water and form insoluble compounds. These compounds tend to form and adhere to the pipe in the immediate vicinity of the point where the corrosion is taking place. This precipitate adheres to the pipe and accumulates in the form of tubercles. The effect of such tuberculation is to reduce the carrying capacity by a decrease in the effective diameter of the pipe and by an increase in the frictional resistance to flow. Where tuberculation is excessive, marked reduction of flow and pressure will occur, and reduction in flow and pressure in sections of a water supply system may be taken as evidence of marked corrosion of the piping system.

2. **Effect on Water.** When corrosion of piping occurs, the metal goes into solution in the water in the form of charged atoms, which are called ions, and therefore the presence of these corrosion products in the water is evidence of the existence of corrosion.

a. *Soluble and Insoluble Metallic Compounds*

The presence of some metal ions in water may be evidenced by visible effects such as the presence of sediment, by an increase in the turbidity of the water, by a change in the color, or by the imparting of a visible coloration to an otherwise satisfactory, colorless water.

b. *Turbidity, Color*

Where iron pipe undergoes corrosion, iron hydroxide is formed, which is usually manifested in the familiar form of brown iron rust, somewhat fluffy in appearance. Occasionally during a heavy draft on the pipe or a change in the direction of flow, a certain amount of the tuberculation of iron hydroxide will be loosened from the main and appear in the tap water as a brownish sediment. Small quantities of iron in solution in a water will impart a turbidity or a yellowish color to the water because of the presence of iron in colloidal form. The presence of high concentrations of copper in solution will impart a bluish cast to the water. Such concentrations are rather unusual in water supplies, but the addition of soap to the water or the presence of a large volume of water, as in a bathtub, will tend to bring out the bluish color. The presence of zinc or lead rarely imparts either color or turbidity to a water.

c. *Taste*

High concentrations of metallic ions will impart a characteristic unpleasant metallic taste to the water. For instance, iron in solution imparts a sharp metallic taste in concentrations of approximately 0.5 to 2.0 ppm.; copper is similarly perceptible in concentrations of about 5 to 10 ppm., and zinc in concentrations of about 20 ppm.

d. *Toxicity*

The presence of metallic ions in water may sometimes affect the health of the consumer. Of the various metals commonly found in water supplies, lead is the most harmful. Concentrations in excess of 0.1 ppm. are considered unsafe for potable supplies. Although there is little or no evidence of damage to health from the presence of either copper or zinc in concentrations such as occur in water supplies, it has been found desirable to limit the concentration of copper to a maximum of 3.0 ppm. and of zinc to 15 ppm. in potable waters. There is no evidence of any physiological effect produced by excessive amounts of iron in solution, but its presence is objectionable for various domestic purposes in concentrations of over 0.3 ppm.

B. Quantitative Estimation of Corrosion

1. **Methods Available for Measuring Corrosion.** Measurement of the extent of corrosion consists in determining either the extent of its action on the metallic piping, its effects on the water stored in the pipes, or both.

Quantitative measurement of the extent of corrosion of the piping system may be based on any of the following methods:

a. Loss of weight of the metal
b. Depth of pitting of the metal in a given time interval
c. Change in the friction coefficient of the pipe
d. Frequency of required meter overhaul and of incidence of failure of domestic plumbing fixtures such as hot water boilers

The first two methods are of value in the determination of the relative corrodibility of various metals and as a guide in the choice of the best metal for a given purpose. The extent of the penetration of a metal due to corrosive action in a given interval of time may be used in gaging the probable useful life of the metal, and comparison of these effects on two or more metals under the same conditions of corrosion may be used to estimate the relative merit of such metals. These methods are of relatively little use in the waterworks field, first, because most corrosion problems are concerned with old piping systems, and, second, because where the choice of new piping is involved the time required to carry out such measurements is usually not available. Once a piping system is installed there is rarely an opportunity to remove sections for study of corrosion effects.

In this connection it may be stated that the so-called "jar test"*—in which a small section of pipe is allowed to stand in contact with a fixed quantity of water for a certain interval of time and the results observed, usually visually—is not a satisfactory method for predicting the results that will be obtained in actual use. The rapid change in the corrosive properties of the water and the unusual initial corrosion effects on the metal make the jar test of little value.

The tuberculation caused by corrosive action offers a satisfactory means for the quantative determination of the extent of corrosive action. The effect of tuberculation is of course to increase the friction loss through the pipe and to reduce the effective diameter of the piping. Where it is known that the tuberculation is caused primarily by corrosion, measurements for the determination of the value of "C" in the Williams and Hazen formula offer a fair criterion of the condition in the mains. However, it must be noted that some forms of pipe incrustation are not related to corrosion.

Where means for such measurements are not available, a more qualitative and less satisfactory method is to look for corrosion and clogging of the meter parts and to note the interval between the required cleanings of meters. Too frequent clogging of meter

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*Not to be confused with the jar test for determining coagulation dosages.

gears indicates excessive corrosion. Similarly, unusually short life of domestic plumbing systems such as hot water boilers and house piping offers a rough indication of the extent of the corrosive effects of the water.

The change in the quality of the water between the source and the consumer's tap after passage through the various service lines offers an indirect measure of the extent of corrosion of the various kinds of metallic piping in the system. An increase in the content of iron, copper, zinc, or lead indicates corrosive action, and its intensity can be estimated by considering the increase in metal concentration with respect to the time of contact between water and pipe.

The dissolved oxygen content of the water can be used as a measure of the extent of corrosion of iron piping. Since oxygen is a primary agent in promoting corrosion and since it is used up in proportion to the amount of iron being dissolved, the drop in the dissolved oxygen content between any two points in a piping system is a measure of the extent of the corrosive action taking place there.

A far less satisfactory indication, yet one which may be of some value, is the extent of the manifestation of some of the effects of corrosion on various plumbing fixtures. For instance, numerous complaints of green stains on white porcelain fixtures is an indication of corrosion of copper or brass pipe. The presence of excessive iron in solution results in numerous complaints of brown stains on plumbing fixtures and the staining of clothes in the process of laundering.

2. **Evaluation of Anti-Corrosion Treatments.** Where steps are taken to reduce the corrosiveness of the water by chemical treatment or otherwise, it is essential that adequate data be obtained to determine the effectiveness of such treatment. As previously indicated, the effects of corrosion are manifested in various ways and after various time intervals. Whether treatment has resulted in a decrease in the corrosion, pitting, or tuberculation in the mains and service lines can be determined only after a period of several months or years. It must be borne n mind that when treatment is begun, the piping system consists of mains and service lines of various metals in varied condition with respect to corrosion. Some may already be badly pitted or tuberculated; some may be relatively free from pits or tubercles; all have coatings of corrosion products, pipe growths, or organic matter of difference densities and protective value. Therefore, when the water applied to such a system is treated to alter its corrosive properties, the manifestation of this change in corrosiveness will be varied and difficult to evaluate immediately. The longer the interval of treatment, the clearer will be the picture of the relative effectiveness of the treatment. Where the treatment has been accompanied by a program of main cleaning, or flushing, some of the immediately apparent effects may be due merely to such cleaning. Any other steps taken in conjunction with the corrosive correction treatment, such as elimination of dead ends, should also be properly evaluated in the overall picture.

In general, the change in the corrosive effects of a water on a piping system can be evaluated only after a period of possibly six months or a year, when a reduction in the frequency of the occurrence of leaks in service lines, clogging and corrosion of the meter parts, clopping of piping, or loss of water pressure at taps indicates the effectiveness of the corrosive correction treatment.

The effectiveness of the treatment first manifests itself in improvement in the condition of the water as drawn from taps throughout the systems. For this purpose it is desirable that as an aid in the determination of the improved water quality certain representative taps be chosen with respect to the type and condition of the water-supply lines of the system and samples of the water be drawn from them under standard conditions of flow for a period of time before treatment is begun. After treatment has been instituted, additional samples can be taken under the same conditions and the change, if any, in the quality of the water can be noted. Such a sampling program should be well planned as to representative samples and be carried out for a sufficient period of time before and after treatment to give a proper picture of the condition of the water. Tests for the various metal ions as well as the dissolved oxygen content will be especially valuable in this work.

3. **Relation of Measurements to Consumer Complaints.** As previously indicated corrosive action is continuously occuring when metal piping is in contact with water. The extent of the action varies with the type of piping and the character of the water supply. The point at which a water is considered sufficiently corrosive to require corrective treatment is quite dependent on the particular community concerned. The waterworks superintendent is concerned especially with corrosion of piping as a cause of leaks or breaks that require repairs, the clogging or corrosion of meter parts, and the tuberculation or clogging of mains and service lines. The consumer, on the other hand, is especially aware of corrosion as it affects the quality of the water. Thus the staining of clothes or of plumbing fixtures by iron or copper compounds is apt to cause complaints to the water department. The appearance of sediment, such as iron rust due to sloughing off of deposits in pipes, will cause considerable objection. There is usually no close relationship between the extent of the corrosive effects, the number of complaints, and the consequent public pressure to require corrective treatment of the water supply. Because of the variation in public reaction to the effects of corrosion, caution must be exercised to avoid evaluating the effects of corrosive treatment solely on the basis of consumer reaction. While the incentive for initiation of corrective treatment in many cases comes from the reaction of the consumers, consumer opinion is not too reliable an index of the effectiveness of the anticorrosion treatment. Reduction in the number of complaints about the appearance of the water and the staining of clothes and fixtures is of value in judging the effectiveness of treatment, but the chief reliance should be placed on the analytical data concerning the water at the various taps before and after treatment. In any case, a sufficient time interval should be allowed before deciding on the effectiveness of treatment, because, as has already been indicated, corrosion is a very slow process and many of its effects are not manifested until an interval of months or years has passed.

II. Fundamental Reactions of Corrosion

No metal is truly stable in the presence of moisture and oxygen, and all metals tend toward ultimate conversion to oxides, hydroxides, or salts of the metallic element, with consequent destruction of the integrity of the metal. There are some metals for which this conversion is so slow that it may be regarded as substantially non-existent; unfortunately all of these are sufficiently rare and expensive to be unavailable for general waterworks use. Those metals that are normally within the economic reach of the waterworks engineer are all subject to corrosion, and the differences among them are small compared with the differences between them and the so-called noble metals.

The most widely accepted theory of the mechanism of corrosion may be called the electro-chemical theory; this theory is supported by an imposing array of observation and experiment. It represents the corrosion reaction as proceeding in a series of four well-defined steps:

Step I—Anodic Reaction. This is the release of metal ions, each carrying one or more positive charges, to the water, together with the liberation of an appropriate number of electrons, each carrying a single negative charge, to the main mass of the metal. It takes place entirely on the surface of the metal. It is represented below for some of the common metals, the term e signifying an electron:

Iron:	**Fe(metal)**	**→Fe⁺⁺**	**+ 2e**
Zinc:	Zn "	→Zn⁺⁺	+ 2e
Lead:	Pb	→Pb⁺⁺	+ 2e
Copper:	Cu	→Cu⁺⁺	+ 2e
Aluminum:	**Al**	**→Al⁺⁺⁺**	**+ 3e**

Step II—Cathodic Reaction The accumulation of electrons in the metal would soon stop the action by building up a negative charge high enugh to prevent the further release of positive ions by sheer electrostatic attraction. However, in the presence of water the surplus electrons can be eliminated by reaction with hydrogen ions from the water. Since the electrons can move freely through the metal, the site of this reaction is not necessarily limited to the same area as that of the anodic reaction and, indeed, often takes place at some distance from it. The reaction is the same for all metals:

$$2H^+ + 2e \rightarrow H_2(gas)$$

When corrosion takes place in a strongly acid solution, the bubbles of hydrogen gas can be seen to form and break away from the surface of the metal. In all other circumstances the hydrogen is removed by another mechanism and may possibly never exist as a gas in the true sense.

Step III—Depolarization. Accumulation of the hydrogen film on the metal again would break the corrosion chain if it were not rapidly eliminated. In the presence of dissolved oxygen this elimination takes place by the reaction of hydrogen and ovygen to form water. The reaction is the same for all metals:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Step IV—Reactions of the Metal Ions. Most of the metal ions released to the water undergo various reactions with ions present in the water. Many of these reactions result in insoluble products that coat the metal and protect it against further corrosion; often the apparent resistance of the metal to corrosion is due to the formation of such coatings. On the other hand, some of these insoluble products crystallize in such a highly previous form that they are of limited value as a protection; iron rust is a good example. The real objective of much of the anti-corrosion treatment of water is to form impervious coatings of one kind or another on the metal by reaction with the substances introduced into the water. A few of the possible reactions of the various metals in natural or treated waters are given here:

Iron: $2Fe^{++} + \frac{1}{2}O_2 + 4OH^- \rightarrow 2H_2O + Fe_2O_3$ (rust)
or $2Fe^{++} + \frac{1}{2}O_2 + 4HCO_3^- \rightarrow 2H_2O + 4CO_2 + Fe_2O_3$
Zinc: $3Zn^{++} + 6OH^- + 2CO_3^= \rightarrow 2ZnCO_3 \cdot 3Zn(OH)_2$ (basic zinc carbonate)

Lead: $Pb^{++} + CO_3^{=} \rightarrow PbCO_3$ (lead carbonate)
or $3Pb^{++} + 2CO_3^{=} + 2OH^- \rightarrow 2PbCO_3 \cdot Pb(OH)_2$ (basic lead carbonate)
Copper: $2Cu^{++} + CO_3^{=} + 2OH^- \rightarrow CuCO_3 \cdot Cu(OH)_2$ (basic copper carbonate)
Aluminum: $2Al^{+++} + 6OH^- \rightarrow 3H_2O + Al_2O_3$ (aluminum oxide)

In the presence of other appropriate ions in the water, such as phasphate or silicate ions, insoluble compounds of the metals with these ions will be formed. None of these reactions will occur unless the necessary ions are present in the water in sufficient quantities.

Corrosion is thus seen to be a complex reaction composed of several steps. Interference with any part of the sequence will alter the course or rate of the entire reaction. This explains why corrosion is affected by a large number of factors, and why statements regarding it are so frequently conflicting or confusing. The conflicts come from disregarding factors which are not obvious but which affect materially some part of the sequence of reactions.

Factors That Influence the Steps in the Corrosion Sequence

Step I—Anodic Reaction. The tendency for a metal to release ions to water is a fundamental property of the metal itself. This tendency can be measured; it is called the oxidation potential of the metal. The noble metals are characterized by low values of the potential, the easily corroded metals by high values. Arranging some of the more common metals in order of decreasing tendency to release ions produces the following results:

Aluminum	Tin
Zinc	Lead
Chromium	Copper
Iron	Silver
Nickel	Gold

If no steps other than the release of ions were involved in corrosion, this series would represent the comparative susceptibility of these metals to corrosion. However, other factors complicate the picture. Aluminum, zinc, and chromium all appear ahead of iron in this series and on this basis alone would be expected to be more susceptible to corrosion than iron, but all three of these metals are much more corrosion-resistant than indicated by their position, because in step IV of the sequence they form impermeable films of oxide or other compounds, whereas iron does not. Under circumstances which prevent the formation of these films, the three metals take their proper place in the series. Such conditions are, however, not likely to occur in practice; hence these metals enjoy a high reputation for resistance to corrosion. Alloying of a metal with another will also alter its relative position in the series.

Step II—Cathodic Reaction. The ease with which hydrogen can be deposited on various metal and other surfaces is subject to considerable variation. It is, for example, more difficult to deposit hydrogen on zinc or tin than on iron, and easier to deposit it on certain oxides of iron than on the metal itself. This accounts in part for the protective action exercised by galvanizing or tinning, and for the localized corrosion or pitting produced by a piece of mill scale on an iron surface. In the latter case the mill scale becomes a cathodic area at which hydrogen is discharged, and the anodic reaction is concentrated in areas near the piece of scale, resulting in a strongly localized attack. Similarly, if two different metals are placed in contact with each other, the one lower in the series shown previously will become the cathodic area and the attack will be concentrated on the one higher in the series.

The rate of discharge of hydrogen is also influenced by the hydrogen-ion concentration (or the pH value) of the water in contact with the metal. Three ranges of hydrogen-ion concentration can be distinguished:

1. The acid range, corresponding to pH values of about 4.5 or lower. In this range the rate of corrosion is directly related to the hydrogen-ion concentration and the hydrogen is evolved directly as gas.

2. The intermediate range, from a pH value of about 4.5 to one of about 10.0. In this range the importance of the hydrogen-ion concentration is small compared to that of other factors, and the corrosion rate varies little, if at all, with pH value. Sometimes this fact is obscured by the influence of the pH value on the formation of protective films of certain types, notably carbonate and silicate films.

3. The alkaline range, corresponding to pH values of 10.0 or greater. In this zone the formation of hydroxide, carbonate, or other films is a direct function of the pH value, and corrosion accordingly again depends greatly on the pH value.

Step III—Depolarization. In waters possessing pH values between 4.5 and 10.0 the depolarization of hydrogen by dissolved oxygen is of great importance to the corrosion sequence. The oxygen concentration and the velocity of flow, which determines how fast fresh oxygen is brought to the metal, both exert a great influence on the rate of corrosion. Complete removal of dissolved oxygen from water will substantially eliminate its power to attack metals in this zone of pH values. Unfortunately, complete removal of dissolved oxygen is seldom feasible in waterworks practice.

If the concentration of oxygen varies at points along the surface of the metal, the areas where the concentration is high become cathodic areas and those where it is low, anodic areas. The attack is concentrated at the anodic areas, and pitting is produced.

Step IV—Reactions of the Metal Ions. Corrosion can be stopped very effectively if a layer of impervious non-metallic material is interposed between the metal surface and the water. Obviously such a material—for example, asphalt or cement—may be deliberately applied to the metal; the effectiveness of such a coating will depend on the imperviousness of the material and the care with which it is applied.

Many of the metals, under suitable conditions, will react with components present in the water to form impervious films that protect the metal from further attack. A complete catalogue of such films would be a major undertaking, but a few of the more common ones may be mentioned here. Films made up of oxides or hydroxides of the metal are numerous; aluminum, chromium, zinc, and iron are familiar examples. Carbonates or basic carbonates of the metal are also common, such as, for example, those formed by zinc and copper. Under special conditions, films of metal silicates and phosphates or of metals combined with organic radicals may be encountered.

In other cases the protecting film may be formed entirely from substances present in the water, without much involvement of the metal ions; examples are the films of calcium carbonate or silicate produced by certain types of anti-corrosion treatment of the water and the protection afforded by some types of organic compounds.

These protecting films vary tremendously in thickness; furthermore, some are effective barriers against corrosion when only one molecule thick, whereas others are relatively ineffective even when present as a heavy deposit. The composition of the water and numerous other factors affect the stability, composition, and physical structure of the films. In short, it is this latter step in the corrosion process that exhibits the greatest complexity and accounts for most of the observed variability in the total rate of attack on metals.

III. Methods of Mitigation of Corrosion

A. Self-Corrosion

Self-corrosion is that resulting from the inherent tendency of all metals to dissolve in water, aqueous solutions of water-soluble materials, or mixtures of water with some other substance which is neither soluble in nor a solvent for water. It is known as electro-chemical corrosion and is the type of corrosion commonly found in piping systems. This discussion applies primarily to water systems. Self-corrosion may be mitigated by

(1) Selection of materials
(2) The use of protective coatings
(3) Treatment of the water

These topics are treated below.

1. **Selection of Materials.** Pipe may be non-metallic and there are many varieties of such pipe available. For the waterworks industry, however, only asbestos-cement pipe, concrete pipe (and masonry conduits), and wooden pipes are at present suitable and practicable. Of these, wooden pipe is now used only as wood stave pipe and its use in the eastern section of the country is practically non-existent except in some waterpower developments.

Asbestos-cement pipe withstands salt water and soft and corrosive waters, but not acids. It is available for mains only and for such use is an important competitor of metallic pipe. It has been found to increase the alkalinity and hardness of water when first installed, an effect which gradually diminishes but may persist for six months or more. Recent methods of manufacture have greatly reduced this leaching characteristic. The *N.E.W.W.A. Journal*, Vol. 51, No. 3 (September 1937), contains a series of papers on the manufacture, laying, and use of asbestos-cement pipe.

Concrete pipe is increasingly used for large mains. The present outstanding example of the use of pipe of this type is the Hultman Aqueduct of the Boston Metropolitan Supply, described in detail in the *N.E.W.W.A. Journal* for September 1941, page 315.

For service connections and interior and other small piping, there are available pipes of various corrosion-resistant metals such as copper, brass, lead, tin, monel, stainless steel, silicon, bronze, nickel-molybdenum-chromium-iron alloys, and others.

Copper is highly resistant to corrosion, but for very soft waters containing large amounts of carbon dioxide, tin-lined copper is to be preferred.

Brass pipe containing 85 per cent or more of copper (red brass) is highly resistant to corrosion. Brass pipe containing 60 per cent or less of copper will dezincify in soft waters; 67 per cent copper (alpha) brass is fairly resistant. Green stains and precipitates may appear when copper or brass pipe is used with very soft waters containing large amounts of carbon dioxide.

Lead pipe should never be used with soft waters because of the toxicity of lead salts. It is suitable for hard waters.

The other corrosion-resistant materials noted above are in general too expensive for use as water pipes and are used mostly in special work, though silicon bronze is used extensively in sewage plants, especially for valves, sluice gates, and stop shutters.

2. **Protective Coatings.** "When pipe material is subjected to corrosive conditions to which it is susceptible, some form of protective coating may be more economical than resorting to a more resistant but more expensive material. Since corrosion may arise from the fluid conveyed by the pipe, from the atmosphere, or from the soil environment in the case of a buried pipe, protection may be needed either internally or externally, or both, depending on circumstances. In the case of internal attack, it may be possible to reduce the corrosive nature of the fluid conveyed."*

Protective coatings and linings for ferrous pipes, valves, and fittings may be (a) non-metallic or (b) metallic.

a. The NON-METALLIC COATINGS most commonly used are paints, asphaltic or bituminous materials, and cement. For special purposes, such as the handling of chlorine and chlorine compounds, rubber-lined pipe is also available.

(i) Paints, while effective against atmospheric corrosion, are less so against underwater and underground corrosion. Therefore they are seldom used for underground pipes but rather for ferrous valves and for submerged steel structures where galvanizing is not practicable or the expense of galvanizing is not warranted. Paints commonly used in waterworks equipment, especially that subjected to submergence or damp atmosphere, have asphaltic or bituminous bases often applied over a base coat of red lead.

(ii) Asphaltic or bituminous linings and coatings are made from natural asphalt or coal-tar pitch. They are applied hot by dipping or by spinning. The A.W.W.A. standard specifications for cast-iron water pipe and fittings cover in detail the approved practices of coating cast-iron pipe with hot coal-tar pitch varnish by dipping. In waterworks practice no other coating is normally applied to cast-iron pipes.

Steel pipes with its greater susceptibility to corrosion and its lesser thickness as compared with cast-iron pipe requires, in general, more attention to coating, especially the external coating of submerged or buried pipes. For steel water mains the A.W.W.A. has formulated specifications for coal-tar enamed coatings (AWWA 7A.5 and 7A.6).

The corrosion protection provided under these specifications is as follows:

For the inside of all steel pipe, a coat of coal-tar primer followed by a hot coat of coal-tar enamel applied either by manual or by mechanical means.

For the outside of pipe, 30 inches and over to be placed underground, a coat of coal-tar primer followed by a hot coat of coal-tar enamel and one coat of water-resistant whitewash.

For the outside of steel pipe smaller than 30 inches to be placed unnderground, a coat of coal-tar primer followed by a hot coat of coal-tar enamel into which is bonded an asbestos felt wrapper, with a finish coat of kraft paper or one coat of water-resistant whitewash.

For the outside of all steel pipe to be placed above ground exposed to the weather, two coats of synthetic red lead primer (or one coat of synthetic red lead primer and one coat of synthetic white enamel) and one coat of aluminum paint.

(iii) Cement linings or coatings. Cement-lined ferrous pipe and fittings, both cast-iron and steel, are used extensively in New England. The A.W.W.A. has prepared specifications (AWWA 7A.7) for "Cement-mortar Protective Coating for Steel Water Pipe 30 inches and over" and a similar specification for cast-iron pipe. Cement-lined pipe, both steel and cast-iron, conforming thereto are commercially available. Mains may also be lined in place by patented processes. Cement linings have the same temporary effect on quality of water when first installed as has asbestos-cement pipe. A cement lining is not wholly impervious to water, but water that penetrates forms an alkaline solution in contact with the iron and tends to inhibit corrosion. Water of low pH value, however, continually reacts with the coating so that cement-lined pipe is not suitable for highly acid waters.

b. *Metal coatings of ferrous pipe.* Of the various metallic coatings and linings available, the most commonly used in waterworks are zinc and lead.

Hot-dip galvanizing is the simplest and commonest method of applying zinc to steel pipe, and the use of pipe galvanized by this method is widespread in interior piping, service connections, and to a limited extent in small mains. Galvanizing provides reasonably good protection against atmospheric corrosion, but it is a poor type of protection with some waters. Zinc is protective because it is anodic with respect to iron and it is intended to be consumed by corrosion. Too long life should not be expected of it. ASTM specification A 120-44 covers hot-dipped zinc-coated steel pipe.

Lead-lined pipe and fittings are suitable for sea water and weak acids but should never be used with soft domestic waters because of toxicity. Since lead is cathodic with respect to iron, a lead lining must be continuous, eliminating any access of the liquid to the iron. This necessitates the use of flanged joints with the lead lining turned back over the face of the flange.

Other metallic linings and coatings are available, but in general they are used mainly for protection against atmospheric corrosion and their value for water pipe and fittings is doubtful. They may be listed briefly here. *Aluminum* may be applied by "calorizing," a process similar to Sherardizing. *Copper, nickel, chromium,* and *cadmium* may be applied by electroplating. There are also processes or treatments which alter the surface of the iron (such as Parkerizing, Bonderizing, anodizing, etc.) and produce moderately corrosion-resistant films of iron oxides or phosphates on the surface.

c. *Natural protective coatings.* Under certain conditions mineral coatings, coatings formed by corrosion products, and by those formed by organic slime, appear to act as corrosion inhibitors. Deposits of mineral coatings of calcium carbonate or of silicates, due to the presence of those substances in the water, may occur to retard corrosion, and this phenomenon explains the lower corrosiveness of hard waters. Oxides, hydroxides, carbonates, basic carbonates, silicates, etc., of the metals, formed by reaction of dissolved metals with substances in the water may form coatings which cause a decrease in the rate of corrosion and may ultimately stop it almost completely. Organic slimes also retard corrosion, a fact accounting partly for the observation that filtered waters are often more corrosive than unfiltered.

3. **Mitigation of Corrosion by Treatment of Water.** There are a number of methods of altering the composition of water so that its corrosive attack on metals is diminished; on analysis, most of these can be classified under one or more of the following groups:

a. *Treatments that reduce the hydrogen-ion concentration of the water.* This covers the use of the ordinary alkaline agents such as soda ash and caustic soda.

b. *Treatments that induce deposition of mineral films on the metal.* This includes treatments to produce calcium carbonate saturation, treatments with silicates, and probably also the treatments with complex phosphates.

c. *Treatments with organic corrosion inhibitors.* These substances deposit organic protective films on the metal; they include an enormous range of compounds, from glue to complex amines.

d. *Treatment with passivating agents.* These are strong oxidizing agents that convert the metal surface to an impervious oxide film.

e. *Treatments to remove dissolved gases, principally dissolved oxygen, secondarily carbon dioxide.*

Items c and d are not applicable as yet to the treatment of drinking water, since the substances used are toxic or otherwise objectionable and yet must be used in moderately large quantity to be effective. Item e is rarely employed in waterworks practice because of technical difficulties, although removal of carbon dioxide by aeration is sometimes practiced as an anti-corrosion measure. In this case its value is dubious, since the oxygen added may be much worse than the carbon dioxide removed. Carbon dioxide is also destroyed in process a. This leaves us with items a and b as our main reliances in corrective treatment of water.

4. **Applications of Methods.** In practice it is often difficult to separate and evaluate methods a and b, since in many waters treatment with alkaline reagents of any sort will produce supersaturation of the water with calcium carbonate, calcium silicate, or a number of other similar compounds capable of acting as protective films. However, in many of the soft waters of New England the separation is very well defined, since the content of calcium is such that no reasonable amount of treatment with the sodium alkalies will produce supersaturation with calcium salts. In this case the two types of treatment can be discussed separately.

a. *Treatment to reduce the hydrogen-ion concentration or to raise the pH value.* This type of treatment has as its objective the slowing of *Step II* in the corrosion chain by making hydrogen ions less available. As previously noted in the theoretical discussion, this procedure is relatively ineffective in the pH zone from 4.5 to 10.0, which covers most natural and treated waters.

The chemicals used in practice are principally soda ash and caustic soda, which are added in amounts sufficient to produce a desired pH value. The statement above regarding the pH zones in which such treatment is effective has been confirmed by the experience of many New England waterworks operators, who have had little success with this type of treatment. It is much more successful in harder waters, but here it succeeds through the combination of the alkaline agents with the calcium of the water to produce protective films.

b. *Treatment to produce deposition of mineral films.*

(i) *Calcium carbonate films.* Water treated so as to produce a condition of saturation or near-saturation with calcium carbonate shows a great decrease in its ability to attack metals, although the attack is not entirely eliminated. The reduction is due to the tendency of the water to deposit, on the metal, films composed in part of calcium carbonate, and in part of carbonates of the metal itself. The type of treatment required to produce a condition of saturation varies with the composition of the water. Hard waters may require only the addition

*"Piping Handbook" by Sabin Crocker.

of soda ash; soft waters with moderate amounts of alkalinity will require only lime, but soft waters of very low alkalinity may need both.

The quantitative relationships involved in such treatments were developed originally by Langelier (*Jour. Amer. Water Works Assn. 25*, 1500, 1936) and extended by him and others (Moore, *Jour. New England Water Works Assn. 52*, 311, 1938; Hoover, *Jour. Amer. Water Works Assn. 30*, 1802, 1938; Langlier, ibid. *38*, 169, 1946) to allow calculation, from the analysis of the water, of the chemicals needed for treatment. Previous to Langlier's work, Baylis had shown how the treatment required could be determined by testing treated samples against calcium carbonates; this is the so-called "marble test," adapted by Enslow for continuous operation with his stability indicator.

While the protection against corrosion afforded by treatment of water to calcium carbonate saturation is not absolute, it is still the most widely used method of controlling corrosion by water treatment. The chemicals used are relatively inexpensive and are already familiar to the waterworks operator through their other applications in waterworks practice. There are few problems involved in dosing, and under-or overdosing for short periods has little noticeable effect.

(ii) *Silicate films.* The addition of soluble silicates (principally sodium silicate) to water in sufficient quantities will produce incipient precipitation of calcium silicate or of silicates of the metals in contact with the water. The metals will tend to become coated wth silicate films, which appear to provide good protection. Not so much is known of the quantitative relationships involved in silicate film formation as in the formation of carbonate films. However, there are numerous instances of successful treatment with silicates in which dosage has been determined by experience. Dosing involves no great problems; the silicates are physiologically harmless and the quantities required are small.

(iii) *Polyphosphate films.* The complex glass-like sodium phospates so-called meta- and pyro-phosphates—are a comparatively new discovery in anti-corrosion treatment. When added to water in relatively small quantities, under proper conditions, there is no doubt that they will materially reduce the rate of attack on ferrous metals. The presence on the metal of a film, only a few molecules thick, of phosphate-containing material, is demonstrated by the appearance of "interference colors." At present this film is believed to consist of compounds of the polyphosphates with the metal or with calcium from the water. The polyphosphates are relatively expensive per pound, but the smallness of the dose required allows them to compete favorably with the anti-corrosion treatments mentioned previously. The treatment is simple in application, involves less increase in the mineral solids of the water than other methods, and has as a consequence been widely adopted during the past few years. In beginning polyphosphate treatment on old, heavily incrusted piping systems, difficulty has occasionally been experienced through the tendency of the polyphosphates to strip off the old deposits and disperse them in the water. Some care is required in the initial application to avoid complaints of turbid or red water.

B. Galvanic Action

As stated in Section II of this report, there is a tendency for each metal to release ions to the water in which it is immersed, and this tendency is different for the different metals. This solution pressure may be expressed in terms of electrical voltage. As already noted, the metals may be arranged in a table in order of decreasing solution pressure. Such a table is referred to as the "electrochemical" or "electromotive" series of the elements. The following series includes the metals commonly encountered in the waterworks field.

Electrochemical Series of the Elements

Aluminum
Chromium
Zinc
Iron
Nickel
Tin
Lead
Hydrogen
Copper
Silver

When two dissimilar metals in contact with each other are immersed in water, the metal that stands higher in the series will tend to release metal ions to the solution, while hydrogen will be formed on the one lower in the series. With reference to the nomenclature used in Section II, the anodic reaction occurs on the metal higher in the series, and the cathodic reaction on the one lower in the series. This results in a flow of current through the solution from the point where the metal is going into solution to the point where hydrogen is being plated out and a similar flow of current in the opposite direction across the junction of the two metals. The metal higher in the series undergoes rapid corrosion, while the corrosion rate of the metal lower in the series is negligible. The entire process is spoken of as "galvanic action." The steps in the process are influenced by the same factors that were described in Section II-A for ordinary corrosion. The extent of galvanic action is also influenced by the difference in potential between the two metals undergoing corrosion and by the relative area of the two metals. If the area of the metal lower in the series (the cathodic area) is large compared with the anodic area, corrosion will be more extensive because there is a large area available for the discharge of the hydrogen that is formed. The extent of galvanic action is also influenced by the conductivity of the solution. In the case of soft waters of very low mneral content and therefore low conductivity, galvanic action will occur only over an area of an inch or so on either side of the junction of the dissimilar metals. With waters of high mineral content, the area of activity may extent somewhat farther.

The solution potential of alloys differs from that of pure metals, and even the processing of a metal will change the electrochemical potential of the section of metal processed. The oxides of a metal likewise have a different solution potential from the original metal. Thus mill scale has a different potential from the iron of the pipe. For these reasons, and because the use of dissimilar metals is quite common in piping systems, galvanic corrosion is quite common. However, as previously stated, the effects of galvanic action are usually limited to a small area in the vicinity of the junction of the dissimilar metals and the extent of galvanic action is minimized by all of the various factors that were pointed out under the discussion of corrosion.

Galvanic action can be kept at a minimum by using the same metal as far as possible throughout the piping system. For example, the use of brass faucets, bronze valve bodies, and brass or bronze fittings with iron piping should be avoided. Where dissimilar metals are absolutely necessary, the choice should be metals as near together in the electromotive series as possible. There have been attempts to reduce the effects of galvanic action by the insertion of a short section of non-conducting piping, such as plastic or hard-rubber piping, between sections of dissimilar metal piping. This procedure will eliminate galvanic action, but it adds materially to the cost and complexity of installation.

C. Stray Current Electrolysis

Stray electric currents may produce corrosion in underground pipes. Under normal conditions only direct currents will produce such corrosion. In a direct-current railway system and in the distribution of direct-current electricity, one side of the system is grounded. If there are defective grounds or defective bonding of the rails of streetcar lines, some current will find its way back to the substation or power station through the earth, and in seeking the path of least resistance current may enter an underground pipe at one point and leave it again at another. Since the pipe at the points or areas where such stray currents leave the pipe is anodic to the earth, corrosion will occur at those points. It may be severe. The remedies consist of providing more direct paths—paths of lower resistance—back to the station. Among these remedies the following may be noted: (a) for streetcar systems: the use of a two-trolley system, thorough bonding of the rails, the use of heavy pipe covering to serve as an insulator in the vicinity of the substation or power plant, insulation of the pipe joints, and the use of drain cables to take the current off the pipe; (b) for ground connections to water pipes: careful checking of all grounds of electric, telephone, and radio systems to see that they have no potential and therefore carry no current.

IMPROVING WATER PLANT OPERATION WITH ACTIVATED SILICA

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Introduction

A MILESTONE in water treatment theory was established twenty-five years ago when colloid chemistry was first seriously considered in relation to floc formation in water and sewage treatment. Those who introduced this innovation in thought used the colloidal explanation to elaborate upon, rather than to create any doubts about the then current explanation of floc formation. It may have been unfortunate for the advancement of coagulation practices that the new information obtained through colloid chemistry was not used to re-interpret coagulation theory. Perhaps the old concepts are deserving of some of Shakespeare's "modest doubt."

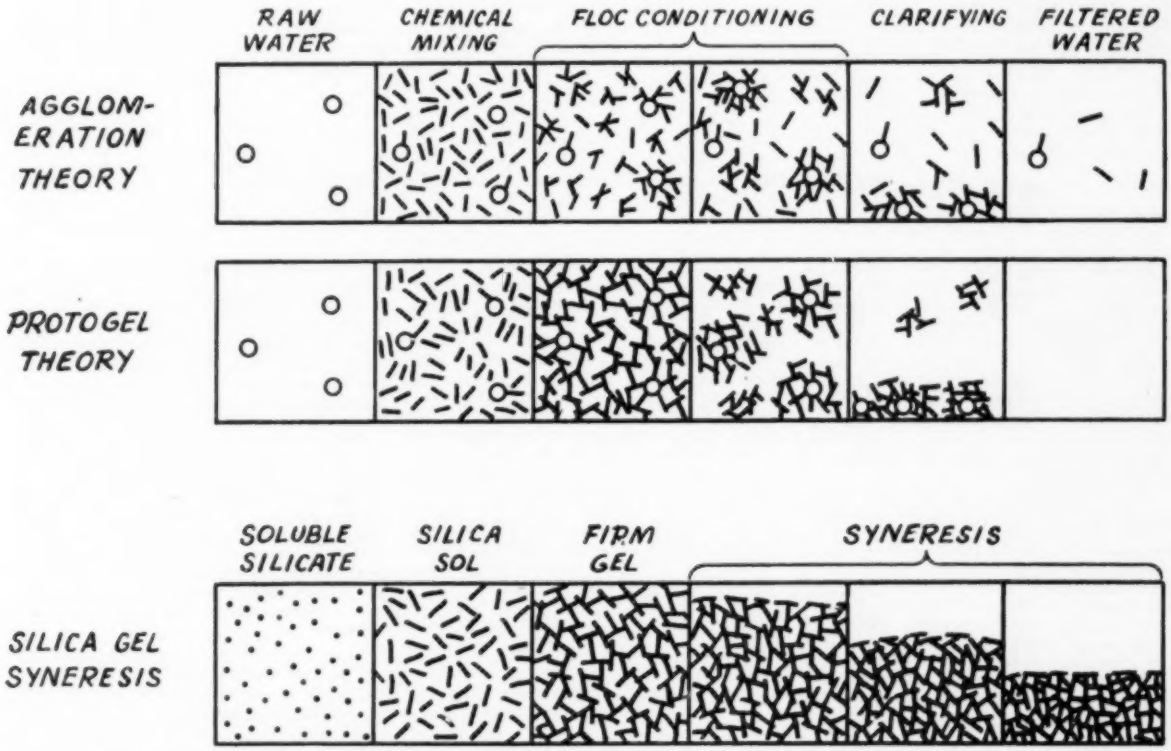
The Agglomeration Theory

The currently accepted agglomeration theory of coagulation is represented at the top of the accompanying figure. Impurities are depicted as circles, with the added alum, or rather its hydrolysis product, indicated as a straight line. In brief, it includes the dissolving of the coagulant, the formation of colloidal particles and the agglomeration of these into flocs which continue to increase in size, because of mechanically induced collisions, until the flocs are large enough to settle and leave clear water. L. H. Enslow, Editor of *Water and Sewage Works*, has likened these dispersions to humidity, fog, mist, and rain.

The agglomeration theory further envisages the removal of impurities by chemical reaction with the ionized coagulant by adsorption on the colloidal particles and by entrapment in colliding or settling flocs. Its major emphasis is on a *growing* floc. In the later stages of floc formation this is easily verified. But the "sweeping" action of a relatively large forming or settling floc may not be the major factor in clarification even when aided by the attraction of particles of unlike electrical charges. Clarification seems to occur while the particles are more highly dispersed. Apparently, to understand that which is mist, it is necessary to look deeper into the fog.

Observing the transition from the colloidally dispersed state to the first evidence of floc formation and the progressive visible growth, one is impressed by the speed with which the colloidal condition "breaks" and by the clarity of the water between the flocs. This would not be expected from the agglomeration theory which, *per se*, is based upon a gradual diminution of concentration of colloidal particles. In a system of diminishing concentration, infinite time would be required for all particles to collide. In actual operation, a substantial percentage of them would never collide and would pass through the filter.

With the collision theory, and with favorable conditions for floc formation, an increase in coagulant concentration would lengthen the time for clarification rather than decrease it. There would be no critical concentration of coagulant. Also, fully as good coagulation would be expected from a divided coagulant feed as from a single



Graphic representation of Agglomeration and Protogel Theories of Coagulation compared to syneresis of gels

addition of equal total amount. Observations contrary to these assumptions have been made. Split treatment is sometimes employed, but the dosages are either in rapid sequence or they may constitute a waste of chemical, when compared with results obtained through a single addition which has been benefited by more favorable conditioning and floc strength.

In the agglomeration theory there is no emphasis on the importance of the flash mixing of chemicals nor is there a disavowal that a long period of conditioning at very low velocity is the equivalent of higher velocity for a shorter period. A new theory can be advanced which, at present, appears to be more in conformity with observed facts and proved practices.

Proposed Protogel Theory

Consideration should be given to the readily observable phenomenon of silica gel syneresis pictured at the bottom of the accompanying figure. Sodium silicates can be dispersed in water, then by neutralization or reaction comparable to the preparation of activated silica for coagulation, the silica can be released and allowed to develop into particles of colloidal dimensions. At certain concentrations of silica, this growth continues until a firm gel is produced. Next, with allowance for time, it is seen that clear and apparently colloid-free water exudes upon the gel surface much as in the manner of perspiration. Finally, shrinkage of the gel is noted and increasing volumes of water are separated. This phenomenon of gel syneresis is the basis of a new "protogel" theory of coagulation.

The proposed "protogel" theory does not depart in any manner from the colloidal chemical features of the agglomeration theory. It interposes one more physical phase. It is suggested that after the colloidal particles have developed sufficient size, they either interlock physically or approach each other so closely that fields of force are interactive. This occurs at concentrations and shear values too low to allow use of the term, gel formation; hence the designation, protogel, signifying the lowest in a series of gel structures.

The effect of an interlocking of colloidal particles would be to enmesh all foreign matter. Subsequently, aided by mechanical agitation and, perhaps, continuing physical-chemical reactions, a shrinkage of the very weak protogel would result in disintegration and the formation of small flocs. With this shrinkage, each floc would become increasingly visible and stronger. The agglomeration theory acknowledges a visible floc to be a gel structure. In the next phase, collisions result in larger flocs. Their settling would be aided by continued shrinkage and the accompanying increase of apparent density.

According to the protogel concept, the whole of the water would have been, at one time, within the protogel structure and would have had to pass through its pores or capillaries. Such ultrafiltration might readily account for the sparkling water observed between forming flocs, and for the quality of the finished product. The entrapment of micro-organisms in the floc can also be better explained by a shrinking structure than by one forming loosely through collisions.

Effect of Mixing on Floc Formation

Flash mixing is essential to assure the uniform distribution of chemical and the formation of an all-inclusive protogel. Separately formed gels, resulting from inadequate chemical dispersion, would not clarify that portion of the water which never has been within their structures. High velocity conditioning is preferable in order to break up this protogel and to aid its syneresis.

If the function of mechanical agitation is not exclusively to promote collisions, there must be another purpose. To understand this, one must appreciate the point of view held by most scientists that gels are particles interlocked in random formation similar to a loosely piled brush heap. Such a brush heap structure is susceptible to having its volume reduced by applied pressure. Though it is not generally so recognized, the floc is subjected to pressure differentials during vertical or horizontal movement. Perhaps in the absence of turbulence these pressures would not be too significant, but neither would there be good floc formation. Small as the pressure effects may be, they are probably of utmost importance for a structure as loosely formed as floc, the fragility of which is, at times, all too evident.

Proper conditioning of a floc appears to depend upon floc toughness. Recent studies indicate that if toughness would permit, it might be preferable to provide highest velocity in the last stage of conditioning. It is desirable to toughen the floc by chemical adjustments. (In a succeeding article, the protogel concept and the considerations of floc toughness are discussed in relation to coagulation at low temperatures.)

Experimental Evaluation of Protogel Theory Needed

It is acknowledged that data are needed to properly evaluate the protogel theory. As with all theories it should be subjected to every doubt that can be advanced. The most obvious criticism exists in the question of whether a protogel, especially one of sufficiently small pore size and of adequate strength to act as an ultrafilter under conditions of turbulence, could be formed at the low chemical concentrations encountered in water clarification. Unfortunately, the writer has not been able to find scientific data which would prove or disprove this point. It would seem to require no more imagination to conceive that this could be so than it does to justify certain phases of the agglomeration theory.

Presentation of the protogel concept has been encouraged by many who hope for an ingression of ideas and for further experimentation in the principles of coagulation.

1—Conventional Flocculation and Sedimentation Units

During the past several years there have been two parallel developments of major importance in coagulation as it is applied to water treatment. Engineers and chemists both have worked toward obtaining higher quality water at production rates much above those formerly regarded as safe practice. A correlation of advanced design and improved chemical treatment has produced effects of mutual benefit so outstanding as to indicate rapid abandonment of low rate operation.

That recognition of this trend is becoming strong in the ranks of the American Water Works Association is evidenced by the action of the Purification Division at the 1946 meeting in St. Louis. The name of the "Committee on Permissible Loadings and Capacity of Water Treatment Plants" was criticized for its negative character, and changed to "Committee on Loadings and Capacity of Water Treatment Processes." Acknowledgment was thereby made that not only new types of equipment but also new chemical processes must be considered for the values that they possess in providing better quality water at lower cost.

Never before have new ideas so broadly challenged the older practices in water purification. In the equipment field, upflow units successfully combine the functions of floc conditioning, sedimentation, and sludge removal. For some water uses, these units also eliminate the need for filtration. For industrial plants, new types of filters are manufactured which are claimed to be effective without advance sedimentation; all of the floc passes on to the filter, which is provided with an automatic backwash. Other new filtration procedures, suitable for clarifying small volumes of water, avoid coagulation completely and reduce chemical treatment to disinfection and odor removal.

In contrast with the basic departures involved in the above mentioned developments, design changes in conventional floc conditioning and settling basins are more evolutionary. Higher velocity chemical mixing and conditioning are used as a result of more intelligent chemical application. Some new devices for flocculation and others for the distribution of water into the sedimentation basin are available. Sludge removal is improved. Conventional filter practices are yielding to new filter design, to higher rates through coarser media, and to the use of surface washing devices.

In comparing the new and the old types of equipment, it is important that each of the various designs be considered in conjunction with the best chemical treatment practices. New coagulation methods can greatly improve the efficiency of conventional floc conditioning, sedimentation, and filtration if some slight modifications of design are provided by the consulting engineer, equipment manufacturer, or plant superintendent. In Part II of this paper it will be shown that the new coagulation methods can correct many water conditions that otherwise prevent upflow equipment from performing at full engineering efficiency.

It is increasingly recognized that both an optimum chemical balance in the water and good engineering design are required for maximum coagulation efficiency and economy. With present design practices it is sometimes impossible to apply improved chemical treatment.

Advancement in Chemical Treatment

In such fields as boiler water treatment, disinfection, and corrosion control, chemistry is being recognized as more fruitful for current study than engineering. Within the past few years, this recognition has produced processes for deionization, methods for disinfection and odor removal using chlorine dioxide, and recommendations for the proper use of sodium silicate and the polyphosphates for corrosion control and scale prevention. In coagulation, the so-called "electronic" water clarifier is more of an engineering development than chemical, although it demonstrates the possibilities in departing from customary coagulating chemicals.

Activated Silica

The chemical development that has affected the largest number of phases of water plant design and operation is "activated silica." Its use is now widely established with excellent service records of several years' duration. The original claims, while spectacular, have been repeatedly verified and new values determined. The recent literature contains a number of statements of approbation by the users.

Reference by A. W. Rumsey[1] to the "magical properties" of activated silica would appear fully substantiated by L. L. Klinger[2], who compiled the benefits of using activated silica with alum in the following manner: "The application of activated silica produces more effective coagulation in both warm and cold water periods; increases floc size and densifies floc; reduces the necessary alum and alkali consumption; broadens the effective pH range of treatment; increases the length of filter runs; buffers sudden chemical changes of raw water characteristics; reduces the raw water color by better than 90 per cent; improves filtered water quality generally and reduces turbidity; prevents "after precipitation" of alum during cold water periods when alum reacts slowly; and decreases dissolved silica."

One familiar with coagulation troubles will promptly find an answer for an unusual number of them among the values of activated silica as described by Klinger. Increasing plant capacity[3], the clarification of difficult types of turbidity[3], and improved softening[4] are additional well-established assets.

With repeated plant scale successes it has been shown that the activated silica can benefit floc formation in nearly all water supplies, that the methods are not too complicated for use by the operators, and that there is a reduction rather than an increase in the silica content of the finished water when used with alum. Reasons for early failures have been determined as ones associated with plant design factors not currently employed or, at least, not in keeping with the present trend. Objections based on the methods for preparation of activated silica will be discussed in a separate paper. Essentially, though, a part of plant design is to make useful chemical processes convenient. Many existing plants can adapt their facilities without much effort, but the greatest convenience will be had when the activated silica process is fitted into the plans for a new plant or when provision is made for its later installation.

Two valid criticisms of activated silica have been that it did not assist coagulation in many cases and that it sometimes caused filter plugging. These problems will be the principal concern of this paper. It is believed that the answers to them will point the way to improving plant design and operation both when activated silica is employed and when the older coagulating procedures are used.

Pretreatment Aids Filtration

The shift in emphasis from filtration to coagulation as the major force in water clarification developed naturally and is just reaching full appreciation. Today a number of water plants, both industrial and municipal, produce better quality water without filtration than was previously achieved with filtration aided by a half-successful chemical application.

C. R. Cox[5] has convincingly stressed the importance of chemical treatment in an article entitled "Pre-treatment of Water for Effective Filtration." Cox, who is well known as Chief of the Bureau of Water Supply, New York State Department of Health, stated: "Improved pretreatment has improved filter operation by reducing the amount of material removed by the filters and has reduced the amount of wash water required. Furthermore, effective pretreatment permits the use of coarser filter sand or anthrafilt than otherwise would be the case, which in turn prolongs filter runs and facilitates washing. Probably the most important aspect of improved pretreatment so secured is the possibility of operating filters at somewhat higher rates than the conventional 2 gpm. per sq. ft., so many of the recent filtration plants are specifically designed to benefit by this situation. The higher rates are not feasible, however, unless the whole plant is designed for this purpose."

High rate of flow operation requires competent operators in addition to efficient pretreatment. Where well-trained persons are employed, public health officials will probably allow the most economical practices which also improve water quality.

Flash Mixing and Point of Chemical Addition

The inclusion of facilities for the flash mixing of chemicals has become standard design practice, but this provision is made only for the coagulant. If soda ash, lime, and sulfuric acid were recognized specifically as coagulant aids, similar in function to activated silica, more consideration might be given to these floc promoters. The easy and careless way to add chemicals for coagulation is to dump them all in at the same point. This works fairly well in many cases but in others failure has led to a better method. The coagulant and the coagulant aid should be added separately with rapid and complete distribution of each one.

The importance of separate addition of coagulant and coagulant aid was established prior to the use of activated silica but it now attains greater significance. As originally recommended with alum clarification, only one order of silica addition was used. Many water supplies did not respond favorably in this way but they gave excellent results when the order of addition was changed. For low turbidity waters it is preferable to introduce the activated silica into the raw water sufficiently early to permit complete distribution ahead of the alum flash mixer. In other cases, the reverse order of addition is required with sufficient retention and agitation to permit the formation of a pin-point floc before the silica addition. This is especially true in color removal and with high turbidities. While silica is usually added ahead of lime for calcium carbonate precipitation, the addition several minutes after the lime seems best for magnesium removal.

A plant designed for silicate treatment should have two points of chemical application at both of which high tubulence is provided. One can be at the suction side of the low lift pump, or at the aerator, if either of these is convenient to the chemical feeding devices and if the coagulant aid should be added first. Coagulant aids do not produce a floc by themselves; therefore, their detention time is of little significance as compared to the thoroughness of their distribution. Flash mix basins having 20-40 seconds' detention are adequate for the coagulant aids if the requisite high turbulence is provided. A well-designed hydraulic jump may also produce effective flash mixing. When the coagulant aid is added after the coagulant, the detention time in the coagulant mix basin should be longer. A detention of at least one minute, and preferably two or three, is suggested to permit formation of pin point alum floc before delivering the water to the second flash mix. When silica is used, there seems to be no occasion to fear breaking up the floc in the second mixing basin.

In one of the water plants of the Consolidated Water Power and Paper Company, Klinger[3] obtains excellent year-around results through the use of two identical flocculating basins each having four minutes' retention. With this colored water, previously difficult to treat, it is necessary to add alum at the entrance to the first mixer and silica to the overflow between the two. This produces a "snow-storm" floc in the second mixer.

When a variable water supply is to be treated, it is advisable to provide double flash mixing basins with a few minutes' retention in each and to arrange the chemical feed lines so that the order of addition may be changed according to the character of the raw water. If it has not been determined that the silicate treatments are to be employed, provision should be made that will permit the later installation of the second flash mixer. With this provision the plant design will be sufficiently flexible to accommodate new treatment practices and it will not become obsolete before its time. Other coagulant aids than activated silica will also benefit from these provisions.

Floc Conditioning and Settling

No special consideration need be given to conditioning a silica-alum floc other than recognized modern practices. The old style end-around or over-and-under baffles can be used with success if there is sufficient retention time and velocity. Frequently in this design, the velocity is too low and the advantages of the silicate treatment are completely lost; sometimes an even poorer result may be obtained than that with alum alone. The silica-alum floc is strong and is improved by high velocity conditioning. This is a prime reason why the silica processes are attaining a place of importance in newly constructed water treatment units of both conventional and upflow types. Mechanical agitation is generally preferred for high velocity floc conditioning.

In proper chemical balance, the silica floc, whether produced with alum in clarification treatments or with calcium carbonate and magnesium hydroxide in the case of softening, forms and settles in about one third the time previously required. The greatest advantage of this comes in the winter months when coagulation is most difficult. In most cases 10-20 minutes of conditioning proves ample with velocities about 50-100 per cent greater than customary. Because of the heavier floc pro-

duced with silica, it is necessary to maintain a somewhat higher velocity to prevent settling in the mixing basin or flumes.

In one plant of rather unusual design, the sludge contour was accurately determined in a settling basin which had only forty-five minutes' retention time. The water passed through the long, narrow, and deep basin at a rate of two gallons per foot per minute. With alum and pH correction, the floc proved too light, and passed out of the basin and into the filters making it impossible to continue operation at the high rate. The sludge pattern showed very little sedimentation in the first third of the basin, then increased in depth through the next third, but remained fairly constant throughout the final third. After cleaning out this sludge and by coagulating with silica and alum, the exact reversal of this pattern was obtained. This change in chemical treatment permitted the continued use of settling basins which would otherwise have required considerable enlargement. The experience also verifies the feasibility of using shorter settling times in new plants.

The most thorough studies of the effect of activated silica on plant design have been those of Baylis[6,7,8], who concluded[8]: "As a result of the development of means of strengthening the coagulation, there is a saving of over 25 per cent in settling time and filtration area regarded as safe design without such means." The detailed description of the Chicago South District Filtration Project indicates this reliance upon activated silica. Whereas the usual Lake Michigan water plant operates with a mixing time of 40-60 minutes, a settling period of 5-6 hours, and a filter rate of 1.5 gpm. per sq. ft.[8], the Chicago plant expects to be able to produce an unusually high quality water without difficulty at a 600 mgd. rate with 28 minutes' mixing, two hour settling, and filter rates of 4.0 gpm. per sq. ft. for continuous operation up to six hours during the summer months[8]. In winter, when the value of activated silica will be relied upon most, the minimum mixing time will be 37 minutes with 2.9 hours' settling and 3.0 gpm. per sq. ft. filtration.

Referring to the capacity characteristics of the Chicago plant, Baylis[8] stated: "The design is not in full accord with the greatest indicated economy, but it is in that direction. It was thought best to be on the safe side and await operating experience on the large plant. . . . Provisions for the preparation and use of this specially prepared silicate constitute the major deviation from conventional treatments in the design of the plant. . . . The extreme conditions, which heretofore have limited the capacity of filtration plants, are to be provided for largely by special treatments of the water." Now that this plant is in operation, it is hoped that the engineers and chemists in charge will continue their valuable scientific research and determine the maximum capacity with various raw water conditions. The publication of such data will materially affect future water plant design.

Filter Performance with Silica-Alum Floc

It has been previously indicated that filtration rates of from 3.0 to 4.0 gpm. per sq. ft. are now becoming a part of regular municipal practice. A number of cities have accepted rates of 3.0 gpm. per sq. ft. without the assistance of floc toughening co-agulant aids[10]. Rates well above 4.0 gpm. per sq. ft. are justified for many industrial plants and, if properly planned, the water quality need not be lower than that now obtained in many cases at half these flow rates.

Baylis[7] clearly proved the advisability of using high rate filtration with coarse filter media. "Filtering material 1.00 mm. effective size is approaching the limit in maximum size of material which may be used when water is treated with acid-treated sodium silicate and aluminum sulfate . . . sand of 1.56 mm. dia. effective size, is too coarse for the silica treated water, though much less coagulated matter passed during periods when the silica was used." In a later article[8], he stated: "Experiments with silicate treated water indicate that sand having an effective size of 1.0 mm. will filter water fully as efficiently as sand of 0.5 mm. without use of silicate. To be well on the safe side, sand between 0.62 mm. and 0.70 mm. effective size is being specified." It may be seen from the foregoing that "torpedo sand" (0.8-1.2 mm.) or corresponding anthrafilt, may become the standard sized media of the future. The advantages of using large filter media are higher rates of flow, longer filter runs, less back-wash water (but higher back-wash rates), freedom from mud balls and clogged areas, and less loss of filter media. Prior to the studies with activated silica, Baylis[11] correlated length of filter runs with sand size and filtration efficiency.

With activated silica capable of giving the highest quality of water at high filtration rates through coarse media, it is natural to ask what it will give with very fine sand. The answer is trouble! One might say "trouble in any language" since Yakovenko[12] evaluated the silicate methods for the Soviet Army and concluded that it improved coagulation but made filtration more difficult. It was not unusual during the early period of introducing the silicate methods to enjoy the sight of the "immense" floc that went into the settling basin and the sparkling water that came out. Although this water needed no more "polish," it did need straining to remove the tiniest floc particles. That should have been easy for the filters, but it wasn't. The alum-silica floc was tough and, in these cases, the sand size was small. In contra-distinction to alum floc, there was no penetration of the filter and the surface sealed over. Quick back-washing ended the trouble—and the silicate test.

Filter plugging may be obtained with floc from alum, iron salts, calcium carbonate, and magnesium hydroxide. When silica becomes a part of this floc the troubles sometimes increase; at other times filter runs become two or three times longer. Careful comparisons between operations in the different plants revealed more than could readily be deduced from any one of them. That a number of factors are involved became evident. First there must be a good floc conditioning. Low velocities will not adequately dewater the tougher floc, settling will be poorer, and an unnecessary amount of floc will pass on to the filter. With the lack of penetration, filter runs will shorten.

Ratio of Coagulant to Coagulant Aid

The second factor is ratio of coagulant to coagulant aid. R. E. Noreus, Technical Manager of the Northwest Paper Company, reported lengthened filter runs as their usual experience[9], but later he suddenly encountered plugging which he described as follows[13]: "In February, with a color of 140, alkalinity 47, and temperature of 32, we gradually reduced the alum treatment from about 4.5 grains per gallon to 4.0, the pH gradually rising from about 5.9 to 6.2. This was the lowest treatment we had ever had. During this period we used 11-13 ppm. of silica and were obtaining 90 per cent color removal. Our filters gradually slowed up and we actually ran out of water twice. We tried washing more frequently without benefiting; we increased the silica to 17 ppm. and then cut it off, without results. Finally, we raised the alum to 6.0 grains per gallon with 11 ppm. of silica, decreasing the pH to 5.6 and our troubles disappeared. We ran into this condition again this spring and again eliminated it in a hurry by increasing the alum ½ to 1 grain without changing the silica, which was being applied at 6-8 ppm. This appears to indicate a definite ratio of alum to silica is important. We do not feel that pH has any bearing on the filter plugging that we encountered but it is due only to the alum added.

"We have had no trouble with mud balls, although this same condition applies to the last few years also. Our filter sand has an effective size of .4-.5 and a uniformity coefficient of approximately 1.6. We have certainly had a very successful period of operation in our filter plant during the past year and attribute this success almost entirely to activated silica."

Ratio of Filter Medium Size to Sedimentation Efficiency

Klinger[3] was able to make an excellent contribution to the elimination of filter troubles as a result of having three different plants for experimentation. In his first plant experience with activated silica, an immediate improvement in water quality was noted, but "after a few hours of operation back-wash increased to a point where it was practically impossible to operate. . . . With a sand size of 0.45 to 0.5 mm. it was possible to back-wash at 12 to 15 gallons per sq. ft. fairly efficiently with alum alone, but this rate . . . was not sufficient for the silica alum floc." After replacing the sand with Anthrafilt of 0.7 to 0.75 mm. average size, thereby permitting better washing at the 12-15 gallon rate, and after installing Palmer agitators, he reported: "With the efficient surface wash produced with Palmer agitation, negligible dirt remained after back-washing, and filter plugging was entirely eliminated. It is interesting to note that one of the original sand beds had not yet been replaced with Anthrafilt at this time, and even this bed operated properly because of efficient surface washing due to the auxiliary agitation."

In a second plant provided with 0.35 to 0.40 mm. sand, Klinger experienced even more severe plugging when activated silica was tried. He explained: "The causes of plugging are mechanical and hydraulic imperfections which have to be rectified by mechanical and hydraulic modifications. These are now being made and it can be said with confidence that the trouble should be definitely eliminated." At his third plant, the filter sand is 0.33 to 0.50 mm. and Palmer agitators are installed. When activated silica was used here, Klinger reported, "An extremely dense and heavy floc resulted. . . . There was no filter plugging. . . . Since this plant is not taxed for capacity, flocculation and sedimentation efficiency is somewhat higher."

The third factor in filter performance, then, is the relation between filter medium size and sedimenation efficiency. When activated silica is used to obtain the higher quality water that is possible with it, there is this alternative: either one must have somewhat great sedimentation time if small sand is to be used or one can have smaller

sedimentation basins if large-sized filter medium is used. Obviously, the latter is the more economical.

Efficiency of Filter Washing

The fourth consideration in handling the silica-alum floc is the efficiency of filter washing. With a heavier, stronger floc it is natural that higher rates of back-wash or some other means of breaking up the floc, such as surface washing devices, should be required. It will be noted that all of the mechanical requirements for optimum plant efficiency with activated silica are in line with the present trend in design. The use of silica permits a more rapid progress in these engineering developments.

Filter Performance with Lime Softening

When activated silica is used wth lime softening, a somewhat different type of filter plugging can be experienced. It is quite different from the calcium carbonate-magnesium hydroxide caking which has been frequently reported with previous softening practices.

Activated silica, prepared by acid neutralization, was used from 1939 to 1941 in a Louisiana softening plant rated at 4.0 mgd. and operating at 2.0 mgd. Turbidities of 600 ppm. were frequent and of 3,000 to 5,000 occasional, but clarification with lime, ferrous sulfate, anl silica was excellent. Objections to the use of sulfuric acid, coupled with filter plugging which probably resulted from failure to properly neutralize the silicate, caused the use of silica to be abandoned. The development of ammonium sulfate as a replacement for sulfuric acid produced a new interest in 1943. Better settling was desired as the water demand had then reached 4.9 mgd. The return to activated silica cut the turbidity applied to the filter from 15-20 ppm. down to 5-7 ppm., and lengthened filter runs. It was noted, however, that there was an increase in the drop of alkalinity through the filters which would seem to indicate a greater rate of sand growth. The operators decided to switch to acid neutralization and promptly encountered filter plugging, whereupon the use of activated silica was again stopped.

In the foregoing example, two precautions for the use of the silicate processes in softening are indicated. In the first place, the preparation of the activated silica must be controlled, using a formula that neutralizes most of the sodium alkalinity of the silicate. In the second, it is not possible to utilize the silicate method at rates higher than nominal capacity unless adequate mechanical agitation is provided for breaking the supersaturation. No mechanical mixing was available in the Louisiana plant; it is not recommended that silicate coagulant aids be tried again until such equipment is provided or the retention time in the baffled conditioning basin is increased.

Black[4] reported on the very successful use of activated silica in Florida, where it has replaced alum in a number of softening plants. He stated that filter runs were greatly lengthened, a softer water was produced and appreciable chemical cost savings were obtained. He pointed out, however, that in Florida also it was noted that at some plants there was a tendency for greater calcium carbonate supersaturation. Black explained: "This is not surprising since the rapid formation of the very large 'feathery' floc particles, some of which begin to settle in the mixing basins at the mixing velocities used, greatly reduces the total exposed area of calcium carbonate particles which in a poorly settled water tend to 'seed' the solution and grow at the expense of the dissolved calcium carbonate. Higher mixing and conditioning velocities are indicated in such cases. . . ."

The writer has followed the record of a Florida softening plant which has used the N-Sol A process for three years and has been advised that the sand is in much better condition than it was prior to this treatment. In no instance has sand growth been observed in Florida as a result of silicate processes. Both the acid and the ammonium sulfate methods of preparing activated silica are used in Florida. Several of those using the acid method observed a cementing of the sand and abandoned the silicate process. No such trouble has been reported with N-Sol A. Upon checking at one plant, a military camp, which had gotten into this trouble with acid treated silicate, it was determined that unwittingly the supply depot had provided a different grade of sodium silicate from that previously used, but this was not noticed by the operator. It had a higher alkali content which should have been taken into account. As soon as the formula was corrected the trouble ended.

The Baylis method calls for neutralization of 85 per cent of the alkalinity of the sodium silicate. In the Florida case just mentioned, only 80 per cent had been neutralized, and plugging occurred. This may indicate that the Baylis formula, developed primarily for use with alum clarification, is too near the border line for good filter results wherever softening is involved. A modified formula carrying neutralization to 95 per cent was recommended by the writer. It is being used successfully without a recurrence of filter trouble.

The N-Sol A, N-Sol C (chlorine reaction), and N-Sol D (sodium bicarbonate), and other N-Sol processes which permit 100 per cent reaction can be used with greater assurance of favorable filter experience and operating economy. To date there is only one exception to the opinion that neutralization should approach 100 per cent. One plant in Pennsylvania adds sodium silicate to lime-softened water without neutralization. No deleterious effects on the filters have been observed, although this same practice has produced troubles elsewhere.

Economies in High Rate Operation

The present upward trend in prices for materials and services will make it more desirable to operate at high flow-rates. Savings made possible by such operation are readily apparent to consultants and equipment manufacturers. They are sometimes overlooked by water plant superintendents who may have an undeniable concern about daily labor and chemical costs.

In purposely general terms, Sheen[14] has indicated that the flocculation and filtration sections of an industrial water plant may constitute a capital investment of $20,000 to $60,000 per mgd. The annual capital charges (depreciation, interest on investment and maintenance) usually figure 20 per cent. Based upon the mean value of $40,000 per mgd., this represents a daily fixed charge, exclusive of labor, of $22 per mgd, assuming operation at full capacity. If this plant could produce the same quality of water at 125 per cent of rated capacity through a different chemical treatment, there would be a credit of about $5.50 per million gallons which could be applied against any increase of chemical cost. In municipal practice, where capital investment is greater by 25 to 50 per cent, there would be a correspondingly greater fixed-charge credit.

It is not implied that chemical methods which boost plant capacity generally increase chemical costs. Lower chemical costs, improved water quality, and flows greater than rating are often observed simultaneously. This occurs most often with waters in the "difficult-to-floc" class that respond very favorably to activated silica. There is a larger classification of "easy-to-floc" waters in which activated silica produces better floc formation and settling. Here, however, the chemical treatment cost with it may be as much as a dollar per million gallons higher than with the use of other coagulant aids. Such a costlier treatment may not be justified while the plant is operating below capacity. If water demand later approaches capacity, and expansion is considered, first thought should be given to increasing capacity through the more favorable chemical treatment.

In keeping with the foregoing possibility, provision should be made in nearly all new plants for immediate or later adoption of a silicate process. Then an unexpected demand or the development of an unusually difficult period of coagulation need not be serious. Another tool for meeting such emergencies with convenience will have been provided. A number of water plants have installed the silicate processes for periodic use only. Some did this for winter benefits, but they subsequently found the values throughout the year to be such that the feed was continuous. Advantages not readily demonstrated in jar tests, such as better filter performance or higher water quality, were responsible.

The proper chemical and mechanical pretreatment of the water will have a very great effect upon initial construction costs, the economy of operation, and the quality of water produced. The selection of the best chemical treatment can with full reliance be based upon jar tests capably run. These, however, are not as simple to conduct as is usually thought. It should be true in the future, though it certainly is not today, that the best results obtainable in jar tests should also be obtainable in plant practice. Equipment can be installed which makes this possible. Cox[8] stated it as follows: "Any great superiority (in jar tests) over the results secured with an existing full-scale unit indicates an inherent inadequacy. The problem then is to determine whether the deficiency of the large basin is one of degree of agitation or period of agitation."

Conclusions

It is not those who have adequately studied the use of activated silica in modern water treating equipment who are skeptical of its values for improving coagulation. In several water treatment plants which have admitted deficiencies, its use has permitted successful operation. Best results with activated silica are obtained in the more numerous instances where it is used with equipment which is in full accord with the present design trend.

In the design and operation of conventional floc conditioning and sedimentation plants, one should consider the probability of producing higher quality water at rates 25 per cent or more above current practice. Such an increase in flow rates may reduce expenditures for equipment and maintenance by an amount exceeding the total chemical cost of coagulation for many waters.

To obtain most efficient results with activated silica in plants of conventional de-

sign, it is recommended that the following provisions be made: (1) Two points of chemical application each with flash mixing. (2) Higher velocity conditioning for a shorter period of time. (3) Reduced detention time for sedimentation. (4) Filtration designed for, if not immediately operated at 4.0 gpm. per sq. ft. for municipal plants, and 6.0 gpm. per sq. ft. or greater for some industrial plants. (5) Coarser filter media to obtain high rates and long filter runs. (6) Increased backwash rates and greater use of surface washing devices.

Activated silica has provided the correct chemical balance in water for clarification, softening and color removal in high rate upflow units, thereby further increasing the operation rates and efficiency. Several examples of upflow operation with silica will be discussed in Part II, which will appear in a forthcoming issue of *Water and Sewage Works.*

References

1 Rumsey, A. W. Silica Sol as a Coagulant Aid. *Midwest Munic. Util.*, Nov.-Dec., 1945, p. 16.

2 Klinger, L. L. Improvements in the Coagulation of Surface Waters with Activated Silica. Summary of Paper presented to Tech. Assoc. of Pulp and Paper Ind. N. Y., Feb. 27, 1946. *Paper Trade J.*, 122, No. 15:44 (1946).

3 Noreus, R. E. The Use of Activated Silica in the Clarification of Highly Colored Water. *Paper Trade J.*, 120, No. 11:45 (1945).

4 Black, A. P. Discussion of "Coagulation Uses of Sodium Silicates." Proc. 5th Annual Water Conf. Eng. Soc. W. Pennsylvania, p. 170 (1944).

5 Cox, C. R. Pretreatment of Water for Effective Filtration. *Public Works*, 76, No. 5:21 (1945).

6 Baylis, J. R. Silicates as Aids to Coagulation. *Journ. A.W.W.A.*, 29, 13:55 (1937).

7 Baylis, J. R. Effect of Silicate Treatment on Quality of Water. *W. W. and Sew.*, 85, 855 (1938).

8 Baylis, J. R. Chemical Treatment Plans for the South District Filtration Plant. *Journ. A.W.W.A.*, 34, 1937 (1942).

9 Dept. of Public Works, Chicago, Ill. Conception, Design and Construction of the South District Filtration Project. *Eng. News Rec.*, 128, 995 (1942).

10 Anonymous. Filtration Rate Increased Without Lowering Quality. *W. W. Eng.*, 97, 604 (1944).

11 Baylis, J. R. Experiences in Filtration. *Journ. A.W.W.A.*, 29, 1010 (1937).

12 Yakovenko, V. A. Judging Coagulants for the Water Supply of the Army in the Field. *Chemical Abstracts*, 37, 5525.

13 Noreus, R. E. Personal Communication from the Northwest Paper Com., Cloquet, Minn., July 19, 1945.

14 Sheen, R. T. Personal Communication from the W. H. & L. D. Betz Laboratories, Consulting Engineers, Philadelphia Pa., April 17, 1946.

2—Upflow Clarification Units

The widespread adoption of upflow water treating units has been an outstanding development in recent years. These plants have many features which justify their consideration for any water clarification problem. Nothing about these newer designs, however, makes it less important to give careful study to the chemical characteristics of the water supply in order to have most efficient operation.

In *Water & Sewage Works* for September, 1946, it was pointed out in Part I of this article that the use of an activated silica sol, as a coagulant aid, can generally improve operation of conventional horizontal-flow plants. Some minor revisions were shown to be necessary to obtain maximum benefits. Since the purpose of the coagulant aid is to correct a deficiency in the chemical balance of the water, it is to be expected that its use will likewise prove advantageous in many upflow plants.

This paper is not concerned with the design of upflow units, but it is, of course, equally as important as in the case of conventional plants, to provide for adequate chemical mixing which in some cases may include provision for reversing the order of addition of chemicals. Also the advantages of large-sized filter media and high rates of filtration would be the same for either upflow or horizontal designs. These points have been covered in Part I of this article.

This discussion will be limited to several instances where the operation of upflow units was strikingly improved by establishing a proper chemical balance in the water with the use of activated silica sols. No further mention will be made of the numerous upflow installations which are performing with full success with the usual coagulants, the use of which is generally known. Experience gained in upflow equipment confirms the findings in plants of conventional design to the effect that activated silica can improve the clarification of the great majority of water supplies. Its adoption would depend on whether or not the advantages exist in adequate degree as was plainly evident in most of the cases to be described.

Importance of Proper Chemical Treatment

The principle on which all upflow designs are based is one of maintaining a suspended floc. Through this "sludgeblanket" or from the surface of the "slurry pool" the clear water is released. It then rises to an overflow weir. For many industrial purposes, the water from the unit may be delivered directly to the clear well without filtration.

It has not been a simple matter in the past to develop consistently the best type of floc for the most efficient operation of any of the various water plant designs. If coagulation is difficult, a small light floc is obtained which does not settle out adequately in conventional plants and therefore passes to the filters. In an upflow unit such floc does not permit a sharp line of demarcation between the body of suspended sludge and the clarified water. The light floc rises with the water and passes over the weir. In spite of mechanical control features, this loss of floc has continued, in a few cases, until the concentration of suspended sludge was too low for normal efficiency.

When an extremely light-floc exists, units operating at high rates may develop "boils." Unequal distribution of the vertical rise of the water or non-uniform flow rates cause such localized disturbances. These sludge boils may be eliminated by the use of mechanical corrections, a lower flow, or a heavier floc. Operation may also be upset by too rapid change in the rate of flow. The seriousness of such fluctuations will depend on their magnitude and the weight of the floc.

Upflow units are equipped with sludge removing devices; nevertheless, it is sometimes necessary to shut the units down for cleaning or repair. This results in complete loss of the suspended floc upon which efficient operation depends. Return to normal operation will be delayed until the proper sludge concentration has been obtained.

The best type of floc for any water clarification equipment is one that is fast-forming, large, tough and heavy. Previously, large flocs were usually light and weak while fast-forming flocs all too frequently failed to produce sparkling water. One other floc characteristic would be highly desirable in plants of upflow design. If the floc density and quality could be varied, there would be an additional control to supplement mechanical features of coagulation. A light floc could be made heavier, and one too heavy to permit the maintenance of the required level of sludge suspension could be made lighter. It now appears that such "tailor-made" flocs are readily obtainable in most waters.

Mention of floc difficulties with upflow operation carries with it an obligation to point out that the engineering principles are not being criticized and that even where such troubles are occasionally encountered the advantages of this type of equipment have justified its use. Several cases are known to the writer in which users of upflow equipment have re-ordered identical units to meet increased demand even before finding that the use of activated silica could solve coagulation problems arising from failure to achieve the optimum chemical balance for most efficient operation of the equipment.

Capacity Increase

The final measure of proper chemical balance for clarifying water in any given piece of equipment is the volume of high quality water which can be produced. Good quality water often may be obtained at low flows without the optimum chemical balance. This deficiency in chemical adjustment, however, will not permit the same quality of high rates and in no case can the best quality be produced except at the proper chemical balance.

An outstanding improvement in upflow operation by proper chemical treatment was reported by R. E. Noreus[13] of the Northwest Paper Co. at Cloquet, Minn. Instead of installing a complete upflow unit, this company utilized an already existing square basin and placed in it the mechanism normally intended for a circular upflow unit. When trial runs were made it was found to be impossible to produce the expected 3,500 gpm. rate with an alum floc. The maximum water output of satisfactory quality was 2,000 gpm. Experiments with pH adjustments, alkalinity changes, floc weighting with clay and studies with various coagulants failed to produce optimum coagulation. The use of an activated silica sol proved to be the answer. Noreus gives the results of using the N-Sol-A process, developed by the Philadelphia Quartz Co., as follows: "The effect of activated silica is to produce a heavy, large, fast-settling floc which leaves 6 to 7 feet of clear water above the sludge bed at any rate up to 4,000

gallons per minute. . . . When the silica treatment is discontinued, the rate must be dropped to 2,000 or lower or the sludge will not settle fast enough."

Near Charleston, W. Va., a standard upflow unit rated at 1,200 gpm. was never operated in excess of 900 gpm. without deterioration in water quality. The alum dosage was 12 ppm. and a small amount of sulfuric acid was being added to further drop the pH. The addition of 4 ppm. of activated silica produced optimum coagulation and immediately improved clarification in both the upflow unit and a parallel conventional flocculation and sedimentation plant. Longer filter runs were obtained in both plants. The same improvement in water quality was maintained when the chemical dosage was changed to 8 ppm. of alum and 2.4 ppm. of silica even when the rate in the upflow unit was increased to 1,200 gpm. When a rate of 1,550 gpm. was tried with the reduced chemical dosage the water quality was poorer, returning to the condition obtained with 12 ppm. of alum at 900 gpm. It was concluded that for an additional cost of $1.20 per million gallons it would be possible to obtain the high quality water with alum and silica at the 1,550 gpm. rate. The ultimate decision, however, was to operate at rated capacity of 1,200 gpm. using the lower alum and silica dosage which costs only a few cents more per million gallons than previous operation with alum at 900 gpm. Additional upflow units have been added to meet an increased water demand.

In Pennsylvania, an upflow unit treating an unusually difficult industrial trade waste could not operate above 56-60 per cent of rated capacity because alum did not produce proper coagulation. The adoption of the N-Sol-A process so improved flocculation that the plant was operated at 90-95 per cent of rating during summer months. Although this degree of efficiency was not maintained throughout the past winter, it was found that proper coagulation could not be obtained at the lower water temperatures unless activated silica was used. With some minor alterations in chemical dosage and equipment, it is expected that rated capacity can be maintained through the year even on this waste.

In a California industrial waste treating plant (not of upflow design) the use of silica made possible the clarification of a salt brine containing 6,000-9,000 ppm. chlorides. Activated silica is also used in an East Coast industrial upflow plant, clarifying sea water for regenerating a zeolite softener. In these cases the weight of the alum-silica floc permitted operation at rates greater than otherwise would have been possible with the high density salt waters.

Color Removal and Cold Water Clarification

Two things that contribute to a light, weak, alum floc are the presence of organic color and a low temperature. Difficulties with cold water clarification will be treated in detail in Part III of this series. Organic coloring matter, as is pointed out by Camp[2], tends to reduce floc densities. Alum floc densities may drop as low as 1.002. It is imperative to correct this condition if color removal and clarification is to be obtained at high rates of flow.

Noreus[1] showed that with a water of 150-400 ppm. color he was able to get 90 per cent color removal with alum at 57 per cent of rated capacity, whereas he obtained 95 per cent removal from alum and silica with flows of 114 per cent of rating. He stated also that by increasing the silica dosage he could obtain nearly as good settling of floc during winter months as he could in the summer.

The color encountered by Noreus is typical of the northern evergreen woods. It is of interest to note that activated silica is also used in conjunction with color removal in upflow units drawing water from the Louisiana bayous, the Florida Everglades, and the New Jersey lowlands. Elsewhere, with conventionally designed plants, it has similarly been shown that color removal and floc settling is improved by the alum-silica floc. With raw water colors of 80-100 alkalinities of 47-53 ppm., and a pH of 6.9-7.1, it has been possible to get 94 per cent color reduction at 34° F. with 110 ppm. of alum and 5 ppm. of silica. Only 88 per cent removal resulted from the same alum dosage alone. If the better color reduction is not important, lower alum dosages may be used. To obtain these results it is essential to add the silica with rapid mixing after the alum has formed a partial floc. In many cases not involving color removal the silica is added ahead of the alum.

Turbidity Removal

Very little experience has been obtained by the writer on the treatment of highly turbid waters in upflow equipment. A case in which the clarification of Delaware River water having a turbidity of 150 ppm. was improved by the addition of small amounts of silica after the alum floc had partially formed will be described later in this paper. The advantages of using silica for the treatment of waters of much higher turbidity in conventional plants have been established by Schworm[3] at St. Louis, where softening is practiced, and more recently by Rumsey[4] at Kansas City, Kan., where alum clarification is used.

In a Texas upflow unit, clarifying a very difficult type of turbidity, 153 ppm. of alum gave only fair results. The high acidity developed by this treatment necessitated heavy soda ash correction. With activated silica it was possible to drop the alum dosage to 51 ppm. The soda ash was proportionately reduced. In subsequent tests it was found possible to provide a satisfactory water by the use of sulfuric acid and alum. This latter method is now employed. Additional tests with silica are planned.

Upflow Softening

One of the difficulties encountered in the clarification of lime softened water with alum is due to the formation of a fine granular or crystalline precipitate when organic matter is present in raw water. This is particularly true if the waters are low in magnesium content or if the removal of calcium only is involved. This type of precipitate has considerable weight, but it apparently has insufficient volume for the best operation in upflow equipment. It was found that the substitution of activated silica for alum as a coagulant gave a very different kind of floc.

Describing the Florida lime-softening operations, Dr. A. P. Black, Consulting Engineer and Professor of Sanitary engineering at the University of Florida, stated[5]: "Ten plants in the area have already substituted silica for all or part of the alum, with results which have been uniformly excellent. The flocs formed are large and 'feathery,' turbidities of settled water have been greatly reduced and filter runs have been increased in practically every instance and in some cases have been more than doubled." Four of these plants are of upflow design. Continuous service records now exceed three years.

Studies on activated silica in the lime softening of high magnesium waters are not sufficiently complete to permit detailed discussion. In one pilot plant upflow study it has been found that the light magnesium hydroxide floc, formed almost in the absence of calcium carbonate, gave trouble which was not corrected by the use of alum as a coagulant. Activated silica, however, established a denser floc which permitted the unit to form the desired sludge concentration and resume normal operation.

"Tailor-made" Floc

In the past there has been a natural reluctance to design for high rate of flow, without realization that the real reason for occasional operating difficulties was the result of inability to create the necessary conditions for proper functioning with the usual coagulant. The weakness of the floc during cold weather, or during difficult raw water conditions, was taken along with the weather as being a correlated phenomenon about which little could be done. It has now been shown that varying the silica dosage can offset the low temperature effect.

It is now possible to change the floc to fit the weather if this should be desirable.

At an upflow plant in New Jersey, a low alkalinity, low turbidity, colored water was treated with full satisfaction using alum and soda ash during the summer months. In winter, however, the alum floc was not sufficiently heavy and was too fragile. For a period of months this unit did not have adequate suspended sludge concentration to permit good operation. When the soda ash was dropped and activated silica used, the unit was operating at full efficiency within twenty-four hours. After several days of excellent operation, the use of silica was discontinued. Within a few hours the suspended floc lightened in weight and passed onto the filters. It was not possible to reestablish efficient operation until the feeding of silica was resumed.

Another manner in which floc of variable weight can be used to good advantage was indicated in an upflow unit operating on Delaware River water at Camden, N.J. This plant was meeting the demand at one-half of its rating and was producing an effluent of satisfactory quality. The desired level of suspended solids was maintained with a motor setting of 4.0 on a scale having a maximum setting of 9.0. If the speed were increased to 6.5, the excessive velocity imparted to the water (excessive for this particular floc weight) caused boils of turbidity which greatly decreased the effluent quality. When 5 ppm. of activated silica were added, the floc immediately increased in weight to such an extent that, at the 6.5 scale setting, insufficient agitation and circulation were being provided. Even at the maximum setting of 9.0 the circulation did not carry the slurry pool above the optimum elevation for good operation.

In the preceding example it can be seen that possibly the optimum degree of floc improvement should not have been used. Too heavy a floc was produced. A lower silica dosage might have shown a better over-all advantage at the low flow. Then, as greater water demand developed, the silica dosage could be raised and floc density increased. As a result of this experiment it is evident that through the use of silica this plant will be able to operate at or above full rate capacity when the occasion arises. The additional flow of water will suspend the floc and will permit lower motor settings, thus re-establishing this control mechanism.

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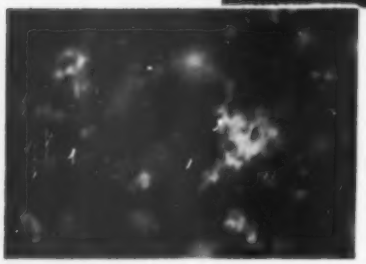
Coagulation with alum alone



Coagulation with alum plus activated silica sol

N-Sol Processes are successfully operating in municipal plants throughout the U.S.A. and in many countries abroad for many different types of water, e.g., flood waters of the Mississippi and Missouri, Lake Michigan, well and surface waters of Florida, highly colored waters of Minnesota and surface waters of Wisconsin. Various waters difficult to coagulate respond favorably to one of the N-Sol Processes.

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N-Sol Processes are popular in the treatment of waste waters to prevent stream pollution. A clear effluent at an economical cost results from treating waste waters of industrial plants such as metal working, textile, paper, food, oil; also from radio active waters.

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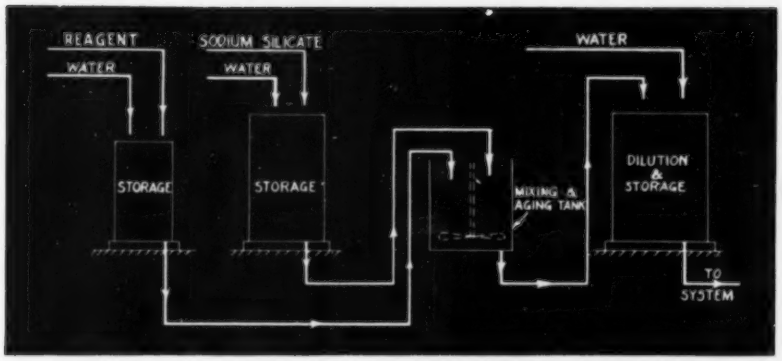
N-Sols are made conveniently at the water plant by diluting N® 41° Baume sodium silicate with water, then adding with vigorous mixing a reacting chemical such as ammonium sulphate, alum, sodium bicarbonate, carbon dioxide, borax, or chlorine. With the N-Sol Processes for preparing activated silica sol, all or nearly all of the alkali in the silicate is neutralized. The choice of the reactant depends on the individual plant requirements and conditions.

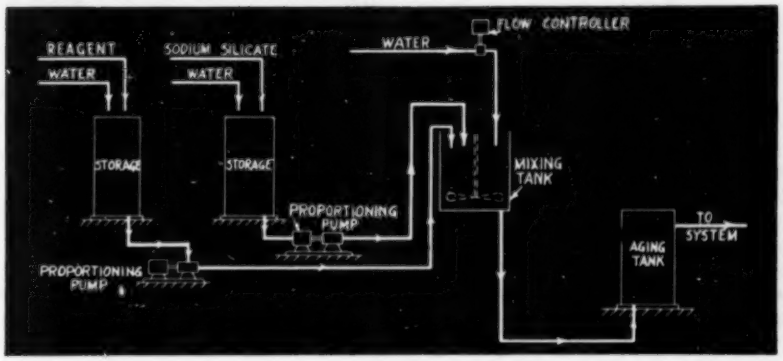
Activated silica sols are also made by reacting N sodium silicate with sulphuric acid (U.S. Pat. No. 2,217,466, J. R. Baylis, City of Chicago).

● ***The following patented N-Sol Processes are licensed to users without royalty fees.***

PROCESS	REACTANT	ADVANTAGE
N-SOL-A (U. S. Pat. 2,444,774)	Ammonium sulphate	Ease of preparation, either batch or continuous. Facilitates the production of chloramines for sterilization.
N-SOL-B (U. S. Pat. 2,310,009)	Alum	Reactant readily available, inexpensive.
N-SOL-C (U. S. Pat. 2,567,285)	Chlorine	Reactant usually available where sterilization is normal practice.
N-SOL-D	Sodium bicarbonate	Used where a highly alkaline salt is desired. For boiler feed water where ammonia is not desired.



Simplified flow diagram for batch preparation of activated silica sol



Flow diagram for continuous preparation of activated silica sol

Sols can be made either by batch or continuous systems. Proportioning devices for continuous feeding of sols are available from most leading water equipment companies.

N-SOL-C

This method is growing in popularity as it offers economy wherever chlorine is available for sterilization. Recently units have been introduced for the continuous preparation and feeding of N-Sol-C. One device mixes sodium silicate and saturated chlorine water, ages the sol in the mixing chamber and ejects it with automatic dilution to the desired concentration for immediate use.

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The selection of the most advantageous treatment and optimum dosage is aided by jar tests. Samples of N Silicate for the purpose, jar test forms as well as suggestions for fuil scale operations are available on request.

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Bulletin 37-3, "Water Corrosion Control"
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Recent developments in water works practice show that bacteria practically cease to exist where Free Residual Chlorination, as accomplished by the Break-Point Process, is employed. Such chlorination assures the production of free available chlorine residuals which have a high killing potential. In many plants bacterial control by the Break-Point Process has been augmented with additional benefits such as improved coagulation, increased color removal, elimination of algal conditions, reduced chemical costs and increased length of filter runs with a resultant saving in wash water.

TYPE MASV AUTOMATIC SOLUTION FEED VISIBLE VACUUM CHLORINATOR

Where unusual or extreme fluctuations in water or sewage flow are encountered, the Type MASV meets the chlorination requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator — rugged construction, simplicity of operation and low maintenance costs.

Type MASV Automatic Visible Vacuum Chlorinator

THE W&T HYPOCHLORINATOR

W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochlorite in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driver by gasoline engine or other similar motive power.

WT SILACTOR

The WT Silactor provides a system for the continuous production of activated silica with chlorine. Raw materials —chlorine and sodium silicate—are withdrawn directly from their own containers without handling or dilution. All chlorine used in the WT Silactor is available for the normal functions of chlorine, such as killing bacteria and algae, or for the oxidation of iron, manganese and other oxidizable material.

WT Silactor

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

CONVENIENCE

W&T is represented in each of the 39 cities by a service staff prepared to give advice on the proper equipment for any chlorination problem.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

"tailor-made" floc is its value in starting up a unit that has been cleaned. It has been stated earlier that these plants do not operate efficiently when the necessary concentration of suspended solids is not present. With the heavy silica-alum floc, however, there is less floc lost during the period when the suspended solids concentration is being built up. Because the silica-alum floc is not as sensitive to pH changes and produces optimum coagulation over a wide range, it is possible to double both the alum and silica feeds during the initial period of operation. In this manner the sludge concentration was increased one per cent per hour. (Percentage was determined as volume settling during 5 minutes in a 100 ml. sample contained in a calibrated graduate.) At the end of seven hours the desired concentration of 7 per cent was reached. The unit then operated efficiently, the chemical dosages were reduced to normal, and sludge draw-off was started. Usually, throughout the history of this unit, it had required seven days to reach the same concentration attained in as many hours with the silica method. This result has been confirmed elsewhere on two other water supplies.

The procedure just mentioned is of particular value in the operation of upflow units. Increased feeding of coagulant and soda ash or lime have previously been used, but it is now found that the heavier alum-silica floc gives quicker and more certain results. During regular operation it is also possible to remedy promptly any effects of excessive sludge removal.

Cost and Water Quality

Just as in the operation of conventional plants, the chemical costs resulting from the adoption of activated silica will vary with each water supply and the efficiency of previous practice. The treatment at one upflow clarification and color removal plant in Louisiana was changed to include silica and the costs dropped from $39.84 to $19.86 per million gallons. At the same location the shift to activated silica in a parallel conventional flocculating and settling basin showed almost identical reduction in treating costs.

Savings accrue from several sources such as the use of a less expensive coagulant or lower coagulant dosage, the elimination of soda ash or lime as a pH correcting agent (usually, but not always, possible), lower wash water consumption, soap savings due to elimination of alum in softening or elimination of lime for pH correction of soft waters, and decreased fixed charges when plant operation at a higher rate of flow is made possible. (This latter factor was considered in Part I.) Lower chemical costs with activated silica have been discussed by a number of authors as indicated in an earlier publication[6] and also as reported by Black[5].

For some waters an increased chemical cost may be expected. Noreus[1] justifies a higher cost as follows: "While use of silica slightly increases the water treatment costs, the reduction in wash water and improvement in water quality are sufficient to offset it." Another advantage which he pointed out was that the use of silica doubled the output of the treating unit. In some cases it is not possible to justify the use of activated silica with present equipment and treating rates.

Water quality is always improved wherever activated silica is used to establish the proper chemical balance. The production of a more sparkling water has been repeatedly confirmed. Baylis[7] first emphasized this in his article on "Effect of Silicate Treatment on Quality of Water," which appeared in *Water Works and Sewerage*. From the time of his earliest work, however, there were some who were not satisfied that the activated silica would be completely removed with the floc. Baylis[8] stated, "Our tests . . . indicate no increase in the silica content of the water." Noreus[1] showed that when a raw water containing 17.5 ppm. silica was treated with alum and 5-12 ppm. of activated silica, the filtered water contained only 8.5 ppm. of silica. This indication that activated silica will actually reduce the raw water silica content has just been confirmed by Klinger of Consolidated Water Power and Paper Co.,[9] who, in plant scale practice in Wisconsin, showed that activated silica and alum reduced the silica content of the finished water 23-32 per cent below that of the raw water clarified with alum alone.

Conclusions

The previously reported values of activated silica coagulant aids for improving operation of conventional water treating plants have been confirmed in a number of upflow units. Correct chemical balance achieved with silica has permitted some units to operate at rates 25 per cent in excess of rated capacity while maintaining excellent water quality. Specific advantages from the use of activated silica in upflow units operating at or above rated capacity are the rapidity with which high sludge concentrations may be reached, the ease with which the desired sludge may be maintained and the low turbidity of the effluent. To date activated silica has been applied only to meet the most difficult coagulation problems. More general acceptance seems assured but will depend upon individual considerations of economy and the need for water of higher quality.

References

1. Noreus, R. E. The Use of Activated Silica in the Clarification of Highly Colored Water. *Paper Trade J.*, 120 No. 11:45 (1945).
2. Camp, T. R. Sedimentation and the Design of Settling Tanks. *Proc. Am. Soc. Civil Engrs.*, 71:445 (1945).
3. Schworm, W. B. New Developments in Coagulation of Water Prior to Filtration. Paper presented to 14th Ann. Missouri Water and Sewerage Conference, Boonville, Mo. (1938).
4. Rumsey, A. W. Silica Sol. as a Coagulant Aid. *Midwest Munic. Util.*, Nov.-Dec., 1945; p-16.
5. Black, A. P. Discussion of "Coagulation Uses of Sodium Silicates." *Proc. 5th Annual Water Conf. Eng. Soc.* Pennsylvania, p-170 (1944).
6. Hay, H. R. Water Purification Methods Involving Sodium Silicates. *Jour. A.W.W.A.*, 36:626 (1944).
7. Baylis, J. R. Effect of Silicate Treatment on Quality of Water. *W.W. & Sew.*, 85:855 (1938).
8. Baylis, J. R. Silicates as Aids to Coagulation. *Jour. A.W.W.A.* 29:1355 (1937)
9. Klinger, L. L. Improvements in the Coagulation of Surface Waters with Activated Silica. *Paper Trade J.*, 122, No. 15: 44-50 (1946).

3—Low Temperature Coagulation

A water supply "just warm enough to flow" would please some consumers, but very few water plant operators. Those operators treating water would prefer it "warm enough to floc." Various devices and practices have been tried to overcome coagulation difficulties in the winter months. Frequently, several remedial measures must be employed simultaneously to produce a satisfactory water quality.

In designing a water plant for use in cold climates, much thought is given to winter operation. The choice of coagulants, type of agitation for floc conditioning, capacity of settling basins (with allwance for ice thickness in extreme cases) and size of filter sand are major considerations. Some of these design factors impose a limitation on the plant operation at other periods of the year when cold water problems do not exist. By solving the low temperature coagulation difficulties many features of plant design can be changed and year-around economies result.

Means of Improving Low Temperature Coagulation

Mechanical means of improving low temperature coagulation have been generally unsuccessful. Longer periods for the conditioning and settling of the floc are frequently provided by the lower winter demand. While flash mixing and high velocity conditioning are recognized as outstanding advancements in warm water (producing better quality at lower chemical costs) they are shunned in winter operation. The old bugaboo of breaking up a fragile floc has necessitated a lowering of conditioning velocities. The best mechanical devices and the use of extremely fine filter sand have not assured good clarification.

It is now common practice to alter the characteristics of a water supply to improve coagulation. Adjustment of alkalinity and pH to a more favorable zone is accomplished with lime, soda ash, excess alum or sulfuric acid. Prechlorination and slime control with copper sulfate often assists. The addition of clay is sometimes resorted to when there is insufficient turbidity. More recently activated silica used in the coagulation process has proved its merit and has become accepted practice.

Water temperature cannot be economically raised to improve coagulation except at plants where a large percentage of the water can be passed through heat exchangers. By this means numerous industrial water plants, using surface supplies, treat at 50-70°F. even during subzero weather. Kansas City, Kan., and Wellsville, N. Y., are examples of large and small municipalities which benefit from a lesser temperature increase by operating in conjunction with a municipal steam power plant. The diversion of condenser water to eliminate intake ice troubles and to aid coagulation has been used at Winnetka, Ill.[1]

In the following discussion an attempt will be made to arrive at a fundamental explanation of the causes of poor winter

coagulation and to describe methods which are successfully coping with this problem.

Effects of Low Temperature

The literature discloses considerable variance in views on the effect of low temperature on the rate of floc formation. Recent evidence, not yet complete because of the many factors involved, indicates that there is not much effect on rate of floc formation. There is, however, an apparent unanimity on the fact that the floc formed is slower settling and possesses less strength. The slower settling is attributed to the slightly greater water density and very appreciable increase in water viscosity. The failure of alum floc alone to develop the same magnitude of toughness in winter months that it does in other periods of the year has been considered to be the result of an unknown influence."

An impressive evaluation of the effects of temperature on the rate of floc formation with Ferrisul was made by T. R. Camp, D. A. Root and B. V. Bhoota at the Massachusetts Institute of Technology[2]. These authors reviewed the generally accepted theory of floc formation and the effects of temperature somewhat as follows. The coagulation (or flocculation) process *per se* is the mechanism by which small colloidal or suspended particles coalesce and form larger particles.

The formation of floc takes place in three phases, according to these authors. The first phase is the production of molecular precipitates by means of chemical reactions which are so rapid as not to be affected materially by temperature when compared to the total time required for floc formation.

The second phase is the formation of colloidal floc particles. The molecularly dispersed and colloidal particles move about rapidly and collide with one another, whereupon they coalesce, forming larger particles until they reach a size that prevents them from moving about under their own kinetic energy. Upon reaching this upper limit of size of colloidal particles, they are still so small as to be barely discernible under the microscope. The speed of this phase of coagulation at 86°F. is twice that near the freezing point of water, but as only 6 to 10 seconds are required for completion of this phase, the effect of temperature is negligible.

The third phase brings the particles together by the mechanically induced motion of the water. The speed of coagulation here was first considered to be proportional to the velocity gradient and independent of the temperature. Thus they concluded that the only appreciable effect of temperature might be that of shifting the optimum pH for floc formation when low dosages of coagulant are employed. A shift in pH of 0.3 unit was shown in these studies. The effect on floc settling was more significant since the velocity of settling varies inversely as the viscosity. For example, at 35°F. the settling period must be 73 per cent longer than at 70°F. to produce the same percentage removal by settling.

It should be pointed out that the M. I. T. authors, in minimizing the effect of temperature on the floc formation, studied coagulation in distilled water and for each temperature shifted the pH to an optimum. It is not known whether the optimum pH shift would be greater or less in natural water supplies. Also, the appraisal of the effect of temperature in the third phase was subsequently modified. Camp and Stein[3] revised the earlier view to acknowledge that a temperature drop from 80°F. to the freezing point would about double the kinematic viscosity and therefore the speed of flocculation will be reduced about 30 per cent by this change in temperature.

From the foregoing it would still be apparent that the effect of low temperature on floc formation, although appreciable, is hardly as important as the effect upon settling. No explanation is given for the "unknown influence" which apparently decreases floc toughness. It is certainly true that if the apparent density of the floc particle could be increased, that is, if the floc could be more completely dewatered, it would settle faster and would have greater toughness. The "protogel theory" of coagulation proposed by the author in the June issue of *Water and Sewage Works* may well provide an explanation for these additional considerations of floc formation, toughness, and settling.

Theory of Floc Formation

In the protogel concept it has been suggested that all of the water and impurities are at one time within a fibrillar network. As this is broken up and compacted by pressure differentials created in floc conditioning, the water must pass out through the interstices. As the floc particle first decreases in size and increases in apparent density, these pores become smaller and smaller until they reach such size that the viscosity of the water provides a resistance to flow which counterbalances further tendency for floc shrinkage. Then growth into larger flocs will provide the maximum toughness and best settling characteristics which can be attained under these conditions for formation. At low temperatures and high water viscosity the equilibrium will be reached with less dewatering of the floc and therefore less toughness and poorer settling.

In conjunction with mechanistic theories for floc formation it must be recognized that the chemical and colloidal balance is of greatest significance. In a mathematical treatment, Camp and Stein[3] have assumed that two particles in stream flow will necessarily collide if calculations indicate that they can be brought within a distance equal to one-half the sum of their two diameters. Such calculations might hold for inert matter but not for electrically charged colloidal particles which frequently constitute a floc. Even with greatly reduced charges on the particles one must expect some orientation rather than random arrangements. The colloidal chemistry explanation for floc formation is too involved for detailed discussion at this time, but it can reasonably be said that it is very important in understanding the mechanism of floc formation as well as of practical significance in meeting problems of difficult coagulation. The benefits of colloidal balance for overcoming the low temperature problem are a case in point.

Floc Toughened by Silica

In 1936 J. R. Baylis began publication of a series of articles in *Water Works and Sewerage* on improved coagulation. These articles are being increasingly recognized for their importance in the advancement of chemical treatment of water. Baylis' research led to the development of a process in which sodium silicate is reacted with sulfuric acid and aged. A product, referred to as "activated silica," is produced. It was found to have a pronounced effect upon the coagulation in Lake Michigan water.

Faster formation, greater toughness, and more rapid settling of the floc were noted along with an outstanding improvement in water quality. The Baylis method, another process developed by A. V. Graf and W. B Schworm, and subsequent contributions by the Philadelphia Quartz Co., have been described elsewhere[4,5]. Alum, ammonium sulfate, chlorine, etc., may be employed with sodium silicate instead of sulfuric acid.

The silicate processes as originally developed were not immediately adopted on a wide scale because the limiting factors, both in preparation and application of the activated silica, were not well understood. More recently, however, these factors for proper control have become known through research in which the writer has cooperated[6,7]. (See parts I and II of this series.) In addition, continuous means for activating the silica have been developed as a substitute for former batch preparation[4,7]. Today, successful service records of one to four years' continued use have been obtained on waters treated for clarification, softening, and color removal.

As a result of the new experiences, recommendations, and process simplifications, the silica coagulant aids are employed at a large number of plants. The smallest treats 0.1 mgd., whereas the Chicago South District Filtration Plant, which is now being completed, is the world's largest and will be able to treat 432 mgd. during the winter months with the Baylis process. In Florida ten water plants, all of them treating less than 3 mgd. and none, of course, operating on cold water, use silica coagulant aids. In Minnesota, where cold water is definitely a problem, N-Sol-A (N-brand silicate reacted with ammonium sulfate) is used for year around operation[6].

Superior Cold-water Coagulation

When Baylis investigated the effects of silicate treatment on the quality of water, he found that the greatest value was obtained during the winter months. His principal conclusions will be reviewed and the data which he accumulated during the cold water months of February, March, and April will be presented here in revised form so that the values of the silicate processes may be even more apparent. His original article[8] may be consulted for the full details of the study.

Using a large pilot plant equipped with five filters which treated slightly more than 0.23 mgd., Baylis determined the amount of suspended material which passed through different size filter media. *The object was to determine whether or not a very high quality water could be obtained while filtering cold water through coarse sand at a rate of 3.2 gallons per sq. ft. per min.*

The quality was measured much more accurately than is possible with turbidimeters. The filtered water was continuously sampled and caused to pass through a cotton plug. The cotton was then ashed to obtain a measure of the amount of suspended material which passed the coarse filters. By this method of determining water quality, even an excellent coagulation (one which produces a sparkling water), shows easily detectable amounts of coagulated matter passing the filters.

During the experiments, the amount of alum used was varied as required to obtain good coagulation. The silica dosage, expressed as SiO_2, approximated 40 per cent of the alum except when lower amounts were employed. Occasionally the results were such as to lead Baylis to the conclusion that they could have been improved had a larger amount been added.

The averages of all tests for the cold water period of February, March, and April are presented in Table I and in the accompanying graph. The data comprise tests of alum alone on 22 days and of silica and alum on 14 days.

Baylis found that alum alone did not produce good coagulation of Lake Michigan water during certain perids and stated that "such periods almost invariably occur when water is at a low temperature. The low temperature and lack of suspended matter in the water which helps reinforce the coagulation probably are the major causes."

Choosing an exceptionally high standard for quality but one which will be increasingly demanded in the future, Baylis concluded that "the ash of the coagulated material found after burning the cotton plugs should average not more than 0.025 ppm." Referring to the use of alum, he continues, "This standard probably would not have been attained with sand of 0.5 mm. effective size and a filtration rate of 2 gal. per sq. ft. per min. during the periods of weak coagulation. The Baylis data show that not once did alum alone reach this standard during February, March, or April with the high rate of filtration. On the other hand, the silica-alum average was 0.016 ppm. for 0.606 mm. sand, 0.029 ppm. for 0.617 mm. Anthrafilt, and also 0.029 ppm. for 0.770 mm. sand. Several tests showed as little as 0.003 and 0.004 ppm. ash.

The Baylis studies on the use of activated silica were made in a pilot plant of conventional floc conditioning and settling design. Outstanding results have also been obtained in the operation of upflow plants. Noreus[6] noted improved color reduction, lengthened filter runs, decreased silica content, and doubled plant capacity. In addition to obtaining these advantages, Noreus more recently summarized his low-temperature coagulation experience in the following statement[7]: "With winter operating conditions we were forced to increase the silica treatment about 100 per cent to obtain equivalent settling conditions as compared to summer. In past years, winter conditions always resulted in poorer quality finished water, whereas with the silica treatment we have now completed twelve months of operation, during which we have encountered no difficulty in maintaining desired water quality regardless of raw water temperature or quality."

The N-Sol activated silica process also proved its value in a cold-water study conducted at Malartic, Quebec. Periods of "trouble" occur at this plant due to formation of light fluffy floc which fills the settling basin within a few days. Prior to a test of silica, the basin had to be cleaned after four days of operation. The addition of 3.5 ppm. activated silica from 12.0 ppm. sodium silicate established a record for the trouble periods of sixteen days' running without cleaning. An even longer run could probably have been obtained with a higher silica dosage. The next run on alum alone was of only three days' duration. The superintendent, Mr. William Duff, further reported that the clarity of water in the settling basin during the activated silica test was the best ever observed.

Such improvements in the character of low temperature coagulation have become commonplace among users of the activated silica processes. It is evident that in some manner a fundamental deficiency of the alum floc is remedied by the introduction of activated silica.

Explanation for Improvements

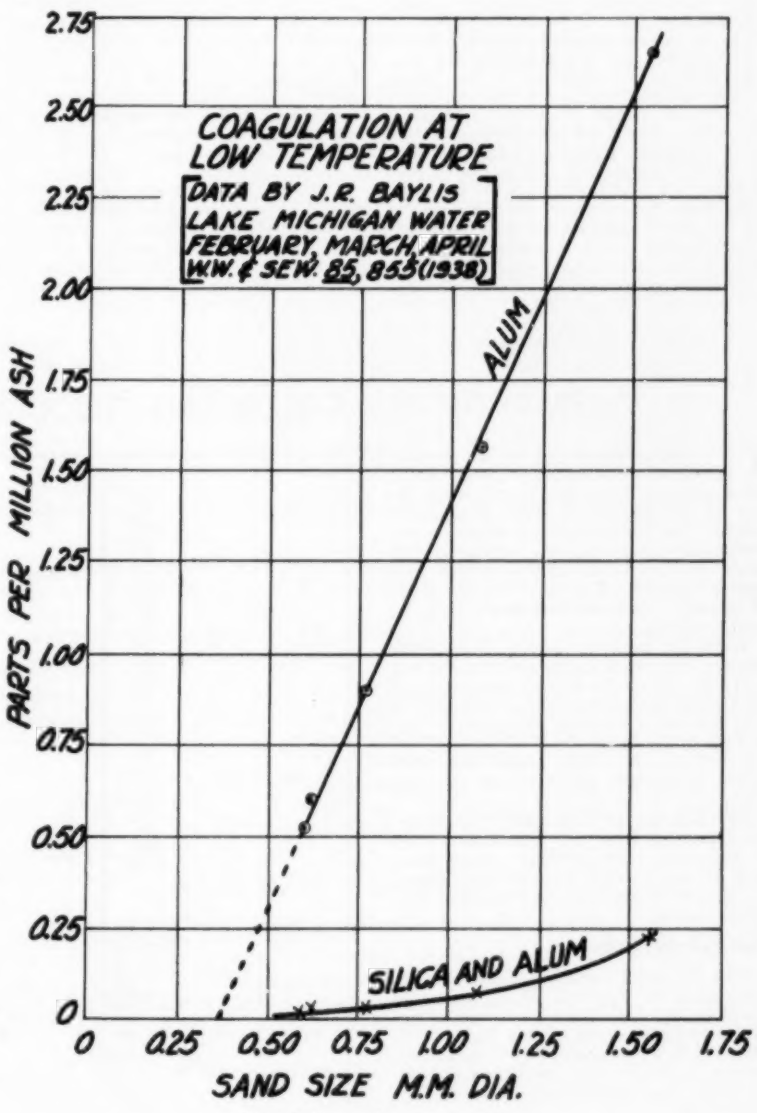
Most of those who have explained coagulation to the water-treating profession have oversimplified the nature of the processes involved. Too much emphasis has been placed upon the elementary chemistry and too little on the colloidal factors which form the basis for the most reasonable explanation. Until very recent years coagulation was improved by shifting the pH to a "zone of optimum coagulation." This is successful in some cases but in others leaves much to be desired. Colloid chemists have long recognized this means of improving coagulation but they also have been fully aware of another possibility which was little used in water treatment. The principle of mutual coagulation applies over a wide range of pH and teaches that optimum coagulation can be obtained by adjusting the balance of colloids of opposite electrical charge.

If coagulation is attempted with alum alone, in the normal pH range for clarification, a positively charged colloid may be obtained which can usually have its charge decreased by shifting the pH. At the optimum condition for coagulation the charge is the smallest possible. In some waters the naturally existing clay may provide sufficient negative charge to neutralize the positively charged alum and permit good clarification without pH adjustment. In other waters it has been found that the

Table I
COAGULATED MATTER PASSING FILTERS, COLLECTED ON COTTON, AND ASHED

Size of filter material in mm.	.606	.617*	.770	1.08	1.56
Average Feb.-Mar.-Apr. Tests—					
Ppm. ash from alum	.520	.596	.901	1.569	2.664
Ppm. ash from alum-silica	.018	.029	.029	0.072	0.226
% reduction by silica	96.5	95.1	96.8	93.4	91.5

* Anthrafilt.



Coagulation at low temperature
Data from Baylis showing the comparative effectiveness of alum alone, and of alum plus silica

addition of clays of high negative charge improved coagulation.

Unfortunately this use of clay was too exclusively interpreted as merely "giving weight to the floc." Activated silica is a material of such small particle size and the amount used is so little as compared to clay that another reason must exist for the heavy floc obtained with it. With silica it is generally unnecessary to adjust the pH to obtain optimum coagulation. Simple neutralization of charges seems to be involved and, in view of this, it can be readily understood why the more finely dispersed activated silica of controllable negative charge is reported to be superior to clay[8].

By establishing a proper balance of electrical forces there is less tendency for the colloidal system to remain in a dispersed state (no floc) or a partially dispersed state (weak floc). Equalization of positive and negative charge permits the floc to compact itself to the greatest possible extent and produces toughness. As was previously mentioned, the tendency for the colloids to reduce their volume may be offset in part by their assuming a gel structure which provides resistance to further compacting. The outward movement of water from such a gel structure is impeded by the submicroscopic pore size and also any increase in viscosity of the water would increase resistance to floc shrinkage.

Optimum clarity of water is obtained when the colloids and suspended matter are most efficiently removed. In an unbalanced system, where colloids of one charge predominate, it is possible to obtain a reasonably good floc without complete removal of the colloidal matter. In a properly adjusted system which is mechanically handled in the best manner, one will simultaneously obtain brilliant clarity and the floc formed will be more compact (tougher) and will settle more rapidly.

The choice between adjusting pH or establishing a balanced condition through the use of a negatively charged colloid, such as activated silica, depends upon the relative economy, convenience, and efficiency in producing a heavy floc under conditions otherwise unfavorable for coagulation. The fact that silica use has been found successful where all attempts at pH adjustment failed[8] indicates that the principle of mutual coagulation may have more merit than the previously applied principle of shifting the pH. This appears to be particularly substantiated in the problem of low temperature coagulation.

Effects Upon Plant Design and Operation

Fear has been responsible for many design features now to be found in water plants which produce a product whose quality is considerably poorer than that which is desirable. Fear of not forming a floc, or of breaking it up, or that the floc will not settle, or that it will penetrate the filters, has caused the installation of features which admittedly are detrimental to operation during other times when the feared conditions do not prevail. Low temperature has been one of the most feared conditions ever since chemical treatment of water supplies was introduced. To a very large extent this condition may be overcome through adoption of the principle of mutual coagulation.

Within certain limits one can now choose the pH range at which he wishes to coagulate and still obtain optimum clarification. (Factors such as color removal limit this choice.) Since all of the added silica is removed with the alum floc and there is only a minor introduction of other reaction products as compared to previous techniques of shifting the pH or alkalinities, the finished water can more nearly approximate the raw water in composition. Increased capacity from existing equipment or economies in new designs are feasible. It is no longer necessary nor advisable to employ fine filter sand where competent plant operation and adequate chemical treatment is provided. Most important is the assurance that in many cases there will be "no difficulty in maintaining the desired water quality regardless of raw water temperature or quality."

References

1. Leipold, C. Raising Water Temperature During Severe Winter. *Jour. A.W.W.A.* 29: 866 (1937).
2. Camp, T. R., Root, D. A., and Bhoota, B. V. Effects of Temperature on Rate of Floc Formation. *Jour. A.W.W.A.* 32: 1913 (1940).
3. Camp, T. R., and Stein, P. C. Velocity Gradients and Internal Work in Fluid Motion. *J. Boston Soc. Civil Engrs.* 30 (4): 219-237 (Oct., 1943).
4. Hay, H. R. Water Purification Methods Involving Sodium Silicates. *Jour. A.W.W.A.* 36: 626 (1944).
5. Hay, H. R. Collodial Silica as an Aid to Floc Formation. Part I. *W. W. & Sew.* 91: 211 (1944).
6. Noreus, R. E. The Use of Activated Silica in the Coagulation of Highly Colored Water. *Paper Trade J.* 120: No. 11, 45 (1945).
7. Klinger, L. L., Improvements in the Coagulation of Surface Waters with Activated Silica. *Paper Trade J.* 122, No. 15 (1946).
8. Baylis, J. R. Effect of Silicate Treatment on Quality of Water. *W. W. & Sew.* 85: 855 (1938)
9. Noreus, R. E. Private Communication (1945).

APPARATUS FOR COLLECTING FLOCCULATED SAMPLES*

THE apparatus shown on the accompanying sketch consists of a wide mouth bottle clamped to a thin board, which in turn is attached to a pole of suitable length. The board is free to rotate on the center pivot and may be turned by the string or light chain attached to the two opposite corners. The bottle may be vented through tubing which extends above the liquid surface.

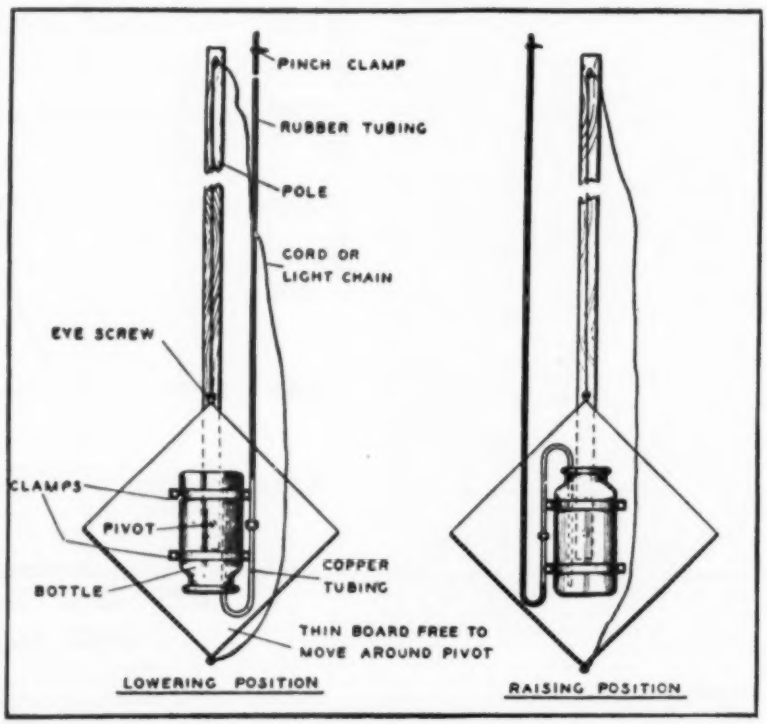
When the bottle is lowered in inverted position, the pinch clamp on the vent line is closed. When the desired sampling level is reached, the pinch clamp is released, so that the floc containing liquid slowly enters the bottle as the air is released. When the bottle is full it is rotated and then raised to upright position with the pull chain.

Through use of this apparatus, flocculated samples from any liquid depth may be collected. The breaking up of flocs, such as occurs when samples are pumped or taken by means of a small mouthed bottle, is avoided.

Acknowledgment

This device employed in studies made by the authors at Ypsilanti, Mich., was perfected by Mr. Geo. Darby, Director of the Westport Laboratories of the Dorr Company. It is a modification of a somewhat similar device earlier developed at the Howard Bend Purification Plant at St. Louis, Mo.

*Contributed by A. J. Fischer and A. Hillman, The Dorr Co.



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Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

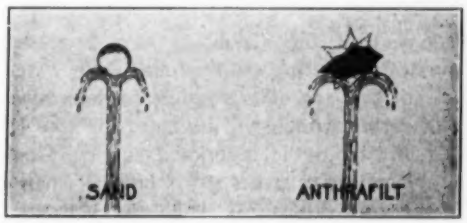
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effectixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

R-222

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AQUA NUCHAR ACTIVATED CARBON

Aqua Nuchar is a quality of activated carbon specifically produced for water purification. Its characteristic is a high adsorptive power for those foreign molecules in water which give rise to objectionable odors. Aqua Nuchar offers the quickest, lowest-cost way to eliminate odors and prevent their recurrence. It is estimated that the year 'round use of Aqua Nuchar Activated Carbon costs on an average less than two cents per capita per year.

With the increase in use of activated carbon in water treatment, competitive carbons and competitive treatments entered the field. Thus it became necessary to develop tests and suitable specifications whereby municipalities would be able to select the activated carbon most suitable for their individual needs.

Development of the Theshold Odor Test supplied the means of measuring odor intensities in water and by means of this test it is possible to determine that quality of carbon which will be most effective for removing odors from the individual supply. Municipal officials are invited to write us for full information regarding this test.

Members of our Research Staff have carried on evaluation tests, comparing Aqua Nuchar with competitive materials for ability to remove odors.

Odors in water are frequently erroneously characterized as tastes. Psychologists recognize four taste sensations; salt, sweet, sour and bitter. Perhaps the greatest cause of odor in water supplies is due to Algae. Odor is occasionally caused by trade wastes, resulting in very severe odor epidemics. Aqua Nuchar removes these odorous compounds in water, thus enabling delivery of a palatable water to the consumer at all times.

Even where there has been no consumer complaint, many plants apply small dosages of Aqua Nuchar in order to prevent a sudden taste or odor condition from getting out of hand. Thus, when tastes and odors develop in a raw water supply, it is only necessary to apply somewhat increased dosages of Aqua Nuchar to control the condition.

AQUA NUCHAR HAS THESE SPECIAL QUALITIES: It disperses more quickly throughout the entire body of water and remains in suspension a longer period of time. Thus the carbon particles have a greater opportunity to contact taste and odor bodies in the water in order to accomplish their REMOVAL BY ADSORPTION.

It is common practice in the design of new plants to provide for activated carbon treatment of the water. Application of Aqua Nuchar Activated Carbon is advisable not only in all water supplies where tastes and odors may be present, but also in water where tastes and odors become apparent after chlorination, but also in water where tastes and odors may become apparent after chlorination. It is a wise precaution under all circumstances.

During floods and high water, odorous compounds may be flushed down to your water intake. Therefore at such times Theshold Odor Tests should be run regularly and you should be prepared with an adequate supply of Aqua Nuchar.

The manufacturers of Aqua Nuchar Activated Carbon offer the services of Technical Field Men to study your methods and recommend the proper place to add activated carbon. They have studied the taste and odor problems of hundreds of plants with surface water supplies and can quickly find the point at which activated carbon should be added to give optimum results.

Warehouse and factory stocks are maintained at strategic points throughout the country so that rush deliveries can usually be made within twenty-four hours or less by local express.

ACTIVATED NUCHAR **CARBON**

Liqro Crude Tall Oil • Indasoil Distilled Tall Oil
Tallene Tall Oil Pitch • Tallex Abietic Acid • Indulin (Lignin)

CONTROLLING TASTE AND ODOR WITH ACTIVATED CARBON*

By E. A. SIGWORTH

Water Purification Division, Ind. Chem. Sales Div., West Virginia Pulp & Paper Co., New York City.

THE importance of palatability of water is being recognized more and more by the water works profession. Great strides have been made in removing color and turbidity and destroying harmful bacteria, so that today most public water supplies are clear and sparkling and safe from the health point of view. Great strides have also been made in improvement of palatability of water since the first application of activated carbon by George Spalding at the New Milford, N.J., plant of the Hackensack Water Co. in 1930. However, many instances still exist where unpalatable water is still being delivered to consumers, sometimes almost continuously and at other times for very short periods. Unfortunately, the consuming public will long remember unpalatable water even though it may be for only one day out of the year. Certainly those individuals desiring to develop good public relations must strive to deliver palatable water consistently.

It must also be borne in mind that the public of today is much more widely traveled than that of a generation ago. Thus consumers have an opportunity to taste water in other localities and can make comparisons which can sometimes react unfavorably to the local supply. Health officials realize that it is essential to deliver water which is perfectly safe from the bacteriological point of view. They also recognize that an unpalatable water can also constitute a health menace by driving consumers to more palatable but perhaps less safe supplies. Therefore, in an indirect way, it is recognized that an unpalatable water can be a possible contributing factor to the cause of illness within a community. With the various available methods for taste and odor control, greater emphasis would seem justified in attempting to produce palatable water.

Causes of Odors

The three main causes of odors are: Algae growths within the water supply, decaying vegetation, and trade wastes. Of these algae are the most prevalent causes of odors as indicated by a survey conducted some years ago. Although there are many varieties of algae, the ones most likely to cause taste and odors fall within approximately 25 to 30 types. These algae, during their life cycle, give off compounds which result in characteristic odors in the water. In some cases, simply by smelling the water it is possible to decide the type of algae which may be causing the odor.

Decaying vegetation usually results in an odor which may be characterized as grassy, musty, swampy, or moldy. These odors result from decomposition of vegetable matter such as grass, under-water weeds, leaves, etc.

Although trade wastes may be the least frequent offender, they can also create the most difficult condition to correct. In other words, odor concentrations may reach extremely high proportions necessitating the entire ingenuity of the operator to reduce them to a palatable level.

Wherever possible, every effort should be made to prevent odors from reaching the water supply. Therefore, preventive measures should be adopted such as copper sulfate treatment for algae control, dredging or damming off shallow areas, and cooperation with plants on the watershed area in order to attempt to reduce trade waste pollution.

Evaluation of Odors

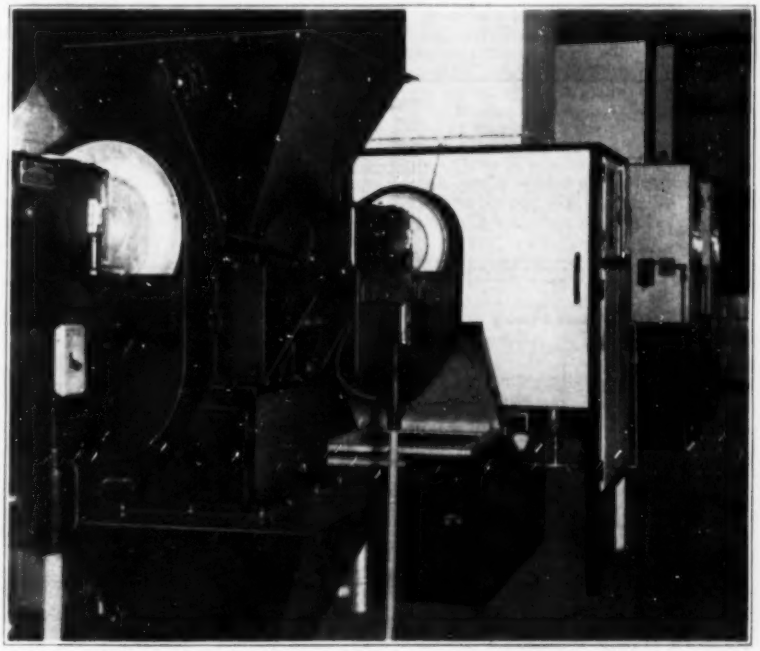
The development of the "Threshold Odor Test" has provided the industry with a satisfactory means for odor evaluation. This test involves diluting a sample of water with varying amounts of odor-free water until the point is reached where odors are just detectable and further dilutions show no detectable odor. By this method, odor concentrations can be assigned definite numbers directly proportional to odor concentration. For example, an odor number of 20 would be 10 times as strong as an odor number value of 28. Thus this test provides the water works operator with a means of determining when it is necessary to institute corrective methods for odor control.

It is also possible with this test to measure the relative efficiency of various treatment methods and chemicals, to determine when the water is palatable and when it is not, and to determine the best point of application for corrective treatment. It has been estimated that a threshold odor of 5 will normally constitute a palatable level for the average consumer. This value assumes an average observer and is based on odor evaluations being conducted on heated samples (60°C) which gives higher color values than those determined on cold samples. If the operator is super-sensitive to odors, the level of palatability might have to be increased, and vice versa.

Activated Carbon

Activated carbon, as most frequently used in water treatment, is a very fine black powder. Activated carbon acts by the phenomenon called *adsorption* which should not be confused with absorption. The concentration of certain specific substances at exposed surfaces is known as adsorption. On the other hand, the picking up of water by a sponge is known as absorption. If a container is filled with a dye solution and a sponge inserted in the solution and withdrawn, absorption takes place. The sponge takes up both water and dye without any change in concentration. In other words, it would be the same as pouring some of the dye solution out of the container. On the other hand, if a piece of clean cloth is dipped into the dye solution, there will be a greater proportion of the dye taken up on the cloth. If successive pieces of cloth are dipped into the dye solution, it will be possible to note a distinct lightening of the color of the dye solution. This phenomenon is known as adsorption.

If activated carbon is added to a dye solution it is frequently possible to obtain complete removal of the dye by adsorption. This phenomenon is explained by exposure of clean surfaces where impurities can concentrate and thus be removed from solution. This is one of the reasons that the carbon used in water purification is such a fine powder. Extremely small particles result in a greater degree of surface exposure, and the porous structure of activated carbon adds to this great amount of surface. Extremely clean surfaces may be considered as the really active patches on which maximum adsorption takes place. So great is the surface exposure obtainable with activated carbon that it has been calculated that one



Omega Dry Feeder for Activated Carbon at Richmond, Va.

*A complete revision and modernization of an article on Taste and Odor Control in an earlier Ref. and Data issue of Water and Sewage Works.

cubic inch of activated carbon can account for internal and external surface of approximately 10,000 square yards. It has also been estimated that one gram of activated carbon (about one normal heaping teaspoonful) will contain approximately 120 billion particles.

The fineness of the carbon particles, coupled with their porous character, gives another advantage in water treatment by permitting the carbon particles to disperse widely throughout the water and remain suspended for long periods of time. This dispersion and suspendability permits greater opportunity for odorous substances to come in contact with the active surfaces which then attract and hold the impurities on the carbon surface. As the carbon particles settle out or are removed by filtration, the odorous compounds are also removed.

It will thus be realized that adsorption of taste and odors with activated carbon actually removes the offender from the water. Therefore, it does not change the odor to some less offending compound nor does it mask objectionable odors.

Feeding Activated Carbon

Activated carbon is insoluble in water and, since it is rather difficult to wet, must be used as a slurry. It can be fed by dry-feed machines which proportion the carbon while in the dry condition, after which the carbon is wet in the solution box and subsequently applied as a carbon slurry. The predominant method of applying carbon is through dry feed machines many of which are available on the market today.

Occasionally some difficulties are encountered with dry-feed machines so that the following suggestions are worthy of consideration. The feeding hopper should be so designed that powdered carbon will not bridge in the hopper thus preventing carbon from reaching the feeding mechanism. The capacity of the dry-feed machine should be more than ample to take care of the most severe odor condition likely to develop within the water treatment plant. The solution box should be designed so as to wet the carbon completely, and the water ejector should be of ample size and capacity to carry the carbon slurry away, even when the machine is operating at maximum capacity.

Some few plants still utilize solution methods of feeding carbon and there is a possibility that this method of carbon handling may increase in the future particularly where large quantities of carbon are involved. Several years ago the Metropolitan Water District of Los Angeles installed a tank for the purpose of storing activated carbon in slurry form. More recently the City of Chicago has done extensive work of a similar nature and has gone a step further.

In the case of the City of Chicago, arrangements were made whereby carbon would be received in bulk hopper cars from which the bulk carbon should be dumped directly into the slurry storage tanks. This method of carbon storage has many advantages such as reducing the dusting effect of carbon throughout the plant, reducing labor costs of handling bags of carbon, making available carbon in large concentrations ready to apply at a moment's notice, and assuring that the carbon particles are thoroughly wet and ready to go into immediate action when applied to the water supply. It is expected in the future that this method of handling carbon will receive wider acceptance but it is desirable to caution anyone interested that extreme care must be utilized in design of equipment, type of metals to be used, type of pumps, etc. (See "Progress in Carbon Slurry Handling at Chicago, Ill.," by John R. Baylis—March 1950 issue, *Taste and Odor Control Journal.*)

Points of Application

In a water treatment plant carbon should be applied at a point prior to filtration or, if no filters are available, prior to coagulation and settling. Thus, in the normal water treatment plant, carbon can be applied to the raw water, mixing basin, settling basin, or directly to the filters.

Where odors develop suddenly, they may get through the plant before being detected, and the carbon should be applied either on top of the filter or to the filter influent. In this manner, carbon is applied to that water which will first reach the consumer. This point of application is most frequently reported to give the greatest efficiency from the carbon for removal of tastes and odors. In many cases, surprisingly low carbon dosages are reported to give exceptionally good results in removing tastes and odors from water supplies by application to the filters. Where odors are usually at low concentration or appear at infrequent intervals, this point of application is usually recommended.

If high dosages of carbon are necessary to correct an odor condition, application of carbon to the filters may result in high loss of head, and possibly in the passage of carbon through the filter beds. Therefore, where carbon is used continuously, it is recommended that the point of application be moved so that it is applied at a point appreciably ahead of filtration. Also, where dosages in excess of 50 pounds per million gallons (6 ppm.) are necessary, carbon should not usually be applied to the filters. Under such circumstances, application is recommended to the mixing basin or to the raw water. In some cases, carbon has been applied part way through the settling basin but caution should be taken to insure that under such circumstances the carbon will have an opportunity to disperse rather uniformly throughout the entire body of water to be treated.

Use of other chemicals can also influence the best point for carbon application. For example, if lime or soda ash is utilized for pH adjustment, it may be desirable to apply carbon prior to these chemicals by as much as 15 to 20 minutes. This is particularly true if the pH of water is raised above the value of 8.5. In many cases alkaline substances are formed which may be less readily adsorbed by activated carbon. Phenol is a specific example, being less readily removed from water by carbon at high pH values.

It is never desirable to apply carbon and chlorine at the same point. Carbon has a tendency to adsorb chlorine just as it adsorbs odorous compounds. Thus some of the chlorine will be taken up by the carbon, thus reducing its potential for disinfecting the water. Also the efficiency of carbon for adsorption of odorous compounds may be slightly decreased. Their points of application should be separated by at least 15 minutes and preferably more.

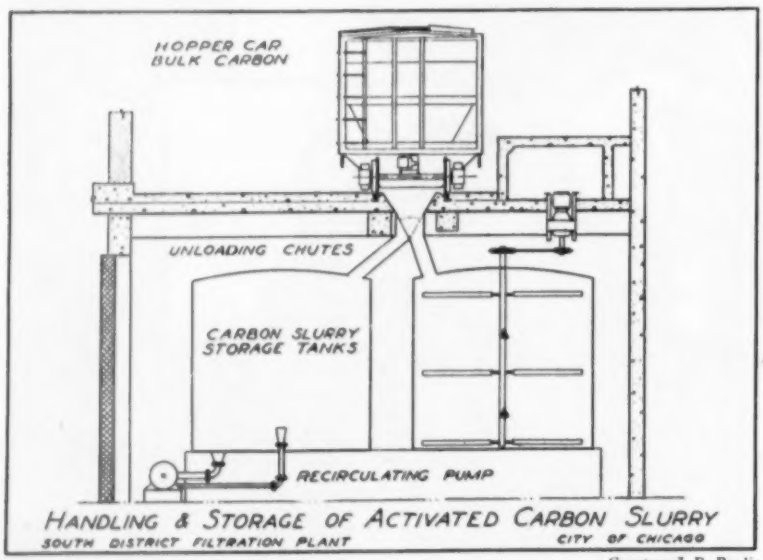
Just which chemical should precede the other will depend to some extent on existing conditions. If chlorine reacts with the odorous compound and makes it more difficult to remove by carbon, then carbon application should precede that of chlorine. Naturally the reverse is true if the chlorinated odorous compound is more readily adsorbed by carbon.

Based on experiences thus far, chlorine is more likely to make the odor compounds more difficult to remove with carbon. Therefore, as a general rule, it would be best that carbon application precede that of chlorine. If pre-chlorination is practiced and the chlorine is applied to the mixing basin, it is suggested that carbon be applied to the raw water as far in advance of reaching the mixing basin as possible (preferably 15 minutes or longer). By following this practice, carbon will have an opportunity to adsorb the odorous compounds before the chlorine has an opportunity to react. It may also be found that the carbon will adsorb other organic compounds which would normally constitute a chlorine demand. Thus, pre-treatment with carbon may possibly result in a reduction of the chlorine demand of the water.

Determining the Carbon Dosage

In many cases, particularly where suitable laboratory facilities are not available, the carbon dosage is determined by "hit-and-miss" methods in actual plant practice. This can frequently result in over or under dosage. More scientific methods are recommended.

In the laboratory, the use of the "Threshold Odor Test" is very successfully used in



Courtesy J. R. Baylis

Diagram of Handling and Storage of Activated Carbon Slurry at Chicago, Ill.

determining the carbon dosage. Naturally, it is necessary first to know to what extent the odors must be removed in order that a palatable water can be delivered. For this purpose, a taste and odor panel is recommended consisting of at least four individuals. Samples of raw water should be chlorinated sufficiently to make the water safe for testing purposes. This water can then be filtered and diluted with varying amounts of odor-free water for tasting purposes. That sample having the least dilution of odor-free water and which is pronounced acceptable by all four tasters can usually be considered as the palatable limit. A threshold odor test can then be conducted on this sample of water and the threshold number will represent the value which must be reached in actual practice.

Having determined the palatable level, samples of water should then be treated with varying amounts of activated carbon. A sample should be collected at a point just prior to any carbon application. If carbon is not being used, a sample of raw water can be collected. To various samples, not to exceed four in number, should be added different dosages of activated carbon. For example, 2, 4, 8, and 16 ppm. If odor concentration is considered to be rather high, it would be desirable to use higher carbon dosages than suggested above.

After addition of the proper carbon dosage, each sample should be treated exactly the same as the existing treatment in the purification plant; this will include alum, lime, chlorine, etc. Individual contact times should parallel as closely as possible actual detention times in the plant. Then samples are finally filtered, preferably through glass wool as the filter medium. This glass wool and all receptacles should be thoroughly rinsed with odor-free water to assure that extraneous odors are not added to any of the samples.

Finally, these treated samples, and also a sample of the raw water, should be evaluated for threshold odor number in accordance with the procedure in "Standard Methods." Results obtained should be plotted on arithmetic graph paper and the curve drawn as accurately as possible to conform to the plotted points. From this curve it should be possible to determine the carbon dosage necessary to produce the threshold number which has previously been determined as acceptable for a palatable water.

In transposing these results to actual plant practice, it should be borne in mind that activated carbon accomplishes better results in plant practice than in small scale laboratory tests. Therefore, it is desirable that the dosage determined in the laboratory should be cut in half for the first plant test. Usually it will be found that half the laboratory dosage will give the desired results in plant practice. Some exceptions to this generalization have been encountered so that the final plant dosage may have to be increased or decreased to give optimum results. For example, if it is found that a laboratory dosage of 12 ppm. of activated carbon is necessary to reach the palatable level, only 6 ppm. carbon should be employed in the first plant scale test. Based on results obtained in the plant, it may be necessary to revise the carbon dosage to as low as 4 ppm. or perhaps as high as 8 or 10 ppm. Such relations, once developed between laboratory and plant results, can usually be utilized as a base in any subsequent tests.

Unfortunately, it is not possible to set any hard and fast rule as to the amount of carbon necessary, even though the threshold number of the raw water is known. For example, in some plants it has been found that one part per million of carbon is necessary for each threshold unit in order to accomplish palatability. Yet, in other parts of the country, this ratio may be one part of carbon for every three or four threshold odor units.

The type of odorous compound is also a contributing factor to this ratio. Therefore, if the type of odor changes suddenly, it is desirable to conduct another evaluation in order to determine the necessary carbon dosage. The reason for this is that some compounds may be easier or more difficult to adsorb by carbon. Also, it should be borne in mind that as odor intensities increase carbon dosages may have to be greatly increased. In other words, if the odor concentration suddenly doubles, it may be necessary to use three times as much carbon in order to remove the objectionable odors. In any case, laboratory tests can constitute a very valuable guide in determining the optimum carbon dosage for plant scale use, always bearing in mind the relation between laboratory and plant results.

In actual plant operation carbon dosages used will vary from as low as two pounds per million gallons to as high as one thousand pounds per million gallons. Extremely high dosages such as 500 pounds per million gallons or more are rather rare and, fortunately, are usually of only very short duration. Although costs of treatment during these short periods of time would seem to be enormous, the average cost over the year is usually found to be very reasonable. If the total carbon costs are calculated on a per capita per year basis, it will be found that the actual cost is very nominal.

Reservoir Application

Difficulties with unpalatable water unfortunately do not limit themselves to systems where water purification facilities exist. Unfiltered reservoir supplies are perhaps even more likely to have odor difficulties, particularly of the algae type, because the water must be clear in order to be suitable for delivery to the public. Since algae thrive more particularly in clear waters, impounded supplies must always face this problem.

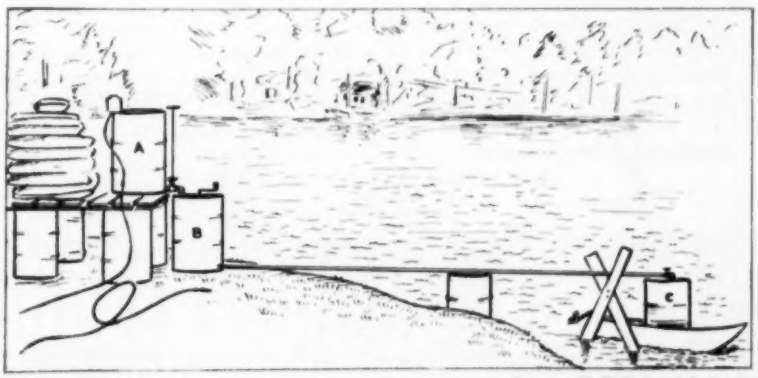
Since activated carbon is a fine black powder which will give a black turbidity to water, it is desirable that treatment be conducted so that little or no carbon reaches the distribution system. The general practice is to treat reservoirs with activated carbon so that no carbon is applied at any point near the reservoir intake. Thus the carbon particles have an opportunity to settle from the water and any small amount that might get into the distribution system would not be noticeable to the consumer. In some instances, carbon has been applied to reservoirs without regard to the proximity of the intake. Under these circumstances the dosage of carbon is usually kept at a minimum of say approximately 1 ppm. so that the small amount of carbon that would get through would not be sufficient to constitute consumer complaints. If the first treatment is insufficient to produce palatable water, further treatments can be made at weekly intervals until the difficulty is corrected and without any serious objections from the consumers.

In the actual application of carbon, the usual practice is to apply it in slurry form. This slurry form of carbon is applied to the reservoir on much the same principle as with copper sulfate. However, in the case of carbon, higher dosages should be applied in the deeper areas so that the carbon concentration in the water is distributed as uniformly as possible.

Preparing the carbon slurry can constitute a problem unless proper equipment is available. An excellent method was worked out by Howard E. Bailey and James B. Studley for applying carbon to a reservoir at Pembroke, Mass. (See "Activated Carbon Treatment of An Open Reservoir," *Water & Sewage Works*, p. 219, June, 1947.) In this particular case, arrangements were made to prepare a carbon slurry on the shore of the pond. This slurry was then piped to the water's edge where the boat could come in for charging. A drum in the boat was used to hold the carbon slurry from which it was discharged to the reservoir. Complete details are described in the above mentioned article.

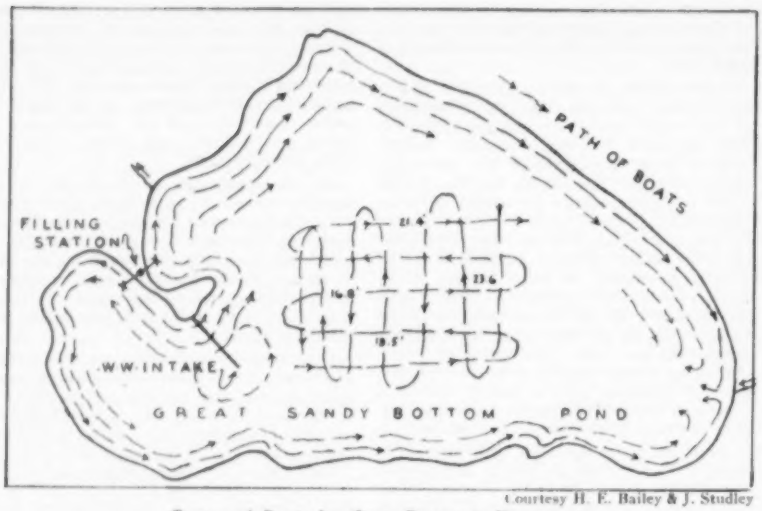
Another procedure was utilized by Fred Luthy at Orange, New Jersey. A boat was equipped with a gasoline motor and pump, and a 50 gallon steel drum for the carbon slurry. Bags of carbon were loaded aboard the boat for wetting. The pump served to supply water to the drum where the carbon slurry was prepared, and the pump also served to force the carbon slurry under pressure through a hose for distribution to the surface of the reservoir. Complete details of this arrangement are included in an article entitled "Powdered Activated Carbon Application to Orange Reservoir"—September 1950 issue, *Taste and Odor Control Journal*.

Based on the small concentrations of carbon utilized thus far in reservoir applications with successful results, there seems reason to believe that this method of treatment constitutes a very efficient procedure. Generally speaking, dosages used are in the very low ranges normally used in water treatment plants. Yet, the production of a palatable water from a very severe odor condition has been the result very consistently. There is also the possibility that the carbon which settles out at the bottom of the reservoir can still accomplish beneficial results. This carbon will still have some



Courtesy H. E. Bailey & J. Studley

Sketch Showing Arrangement for Carbon Treatment Plant at Open Reservoir



Courtesy H. E. Bailey & J. Studley

Course of Boats for Open Reservoir Treatment
(Great Sandy Bottom Pond, Rockland, Mass.—108 Acres, 300 mil. gal.)

reserve capacity for odor adsorption, and it may act toward stabilizing any decomposition odors which might normally develop at the reservoir bottom.

Blackout of Algae

In addition to foods normally present in water, algae require sunlight and suitable temperatures for propagation. The fact that activated carbon gives a dark appearance to water was considered as a possibility for eliminating the sunlight which is considered one of the essentials for algae growths. The first application for this purpose is credited to the late William P. Bailey at Council Bluffs, Iowa. In the application of activated carbon for this purpose, the carbon is thoroughly wet and applied as a slurry to the entire surface of the body of water to be treated. For successful results, application is made once or twice each day during periods favorable to algae growths. Thus application is usually limited to the summer months and also only to days of prolonged sunlight. Naturally, during cloudy days, carbon application is not necessary.

It remained for Hartung and Lischer of the St. Louis County Water Department, St. Louis, Missouri, to determine the necessary carbon dosage to treat a particular water surface. Based on their studies, it was found that a dosage of approximately a quarter of a pound of carbon would successfully black out a water surface of 1,000 square feet. Thus it must be realized that the dosage necessary for carbon blackout is usually far below that necessary for accomplishing taste and odor control. However, if carbon is necessary for correction of odors, the amount used for algae blackout would automatically reduce the quantity of carbon necessary for eliminating odor conditions. Studies in the field have shown activated carbon to be the most universally successful answer to taste and odor problems. Some reported failures have been due to improper point of application or an attempt to accomplish results with too small a dosage. It is safe to state that almost all odors can be reduced to a palatable level with activated carbon if a sufficient quantity is used at the proper point of application.

CONCRETE

Quantities of Materials for One Cu. Yd. Rammed Concrete Based on Barrel of 3.8 Cu. Ft.

Proportions	Using ¾-in. Gravel and Under, Sand Screened Out: Cement Barrels	Sand Cu. Yds.	Gravel Cu. Yds.	Using 1-in Stone and Under, Dust Screened Out: Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.
1 1½ :3	1.71	0.39	0.78	1.85	0.42	0.84
1 2 :4	1.34	0.41	0.81	1.46	0.44	0.89
1 2 :5	1.17	0.36	0.89	1.27	0.39	0.97
1 2½ :5	1.10	0.42	0.83	1.19	0.46	0.91
1 3 :5	1.03	0.47	0.78	1.11	0.51	0.85
1 3 :6	0.92	0.42	0.84	1.01	0.46	0.92
1 3½ :6	0.88	0.46	0.80	0.95	0.50	0.87
1 3 :7	0.84	0.38	0.89	0.91	0.42	0.97
1 3½ :7	0.85	0.43	0.85	0.87	0.47	0.93
1 4 :7	0.77	0.47	0.81	0.83	0.51	0.89
1 4 :8	0.71	0.43	0.86	0.77	0.47	0.93

Proportions	Using 2½-in. Stone, Most Small Stone Screened Out: Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.	Using 2½-in. Stone and Under, Dust Screened Out: Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.
1:1 ½ :3	1.96	0.45	0.89	1.90	0.43	0.87
1:2 :4	1.53	0.47	0.93	1.48	0.45	0.90
1:2 :5	1.33	0.39	1.03	1.29	0.39	0.98
1:2½ :5	1.26	0.48	0.95	1.21	0.46	0.91
1:3 :5	1.17	0.54	0.89	1.14	0.52	0.87
1:3 :6	1.06	0.48	0.97	1.02	0.47	0.93
1:3½ :6	1.00	0.53	0.92	0.97	0.51	0.89
1:3 :7	0.94	0.42	1.05	0.92	0.42	0.98
1:3½ :7	0.91	0.49	0.98	0.89	0.47	0.95
1:4 :7	0.87	0.53	0.93	0.84	0.51	0.90
1:4 :8	0.81	0.49	0.98	0.78	0.48	0.95

Figure about 1¼ cu. yds. of pit run gravel to make one cubic yard of rammed concrete.

Variations in fineness of the sand and the compacting quality of the concrete may affect the above quantities 5 to 10% in either direction.

Weights of Cement, Crushed Stone, Gravel and Sand

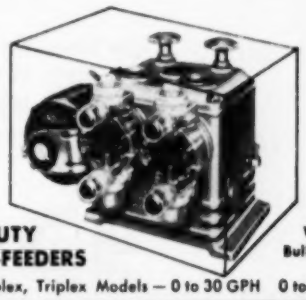
Material	Weight per Cu. Yd.	Material	Weight per Cu. Yd.
Bank sand	2,500	Screenings	2,500
Torpedo sand	3,000	Gravel	3,000
Crushed stone	2,500	Roofing Gravel	3,000

Portland cement weighs 94 lbs. per bag, or 376 lbs. per bbl. One bag is equivalent to 1 cu. ft.

% PROPORTIONEERS %

EASY-TO-INSTALL PACKAGES

Multiple feeding of chemicals can be accomplished with this one package. Feeds one or more chemicals used for treatment of water or sewage.

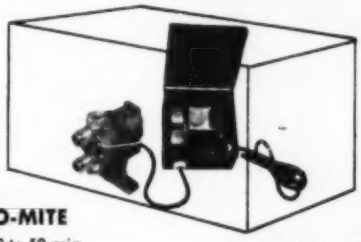


HEAVY DUTY CHEM-O-FEEDERS

Write for Bulletin 1225-1

Simplex, Duplex, Triplex Models — 0 to 30 GPH 0 to 100 psig.

For very small water supplies having pollution or taste and odor troubles — camps, country estates, private homes, farms, roadside stands, etc.

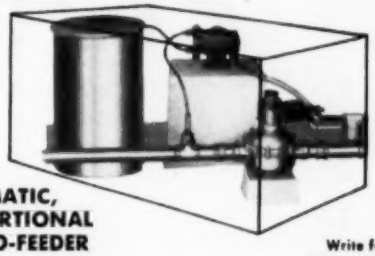


CHLOR-O-MITE

⅛ to 1 GPH 0 to 50 psig.

Write for Bulletin 1910-2

Protects small gravity water supplies where rate of flow varies from minute to minute. Ideal for remote locations where electricity is not available.

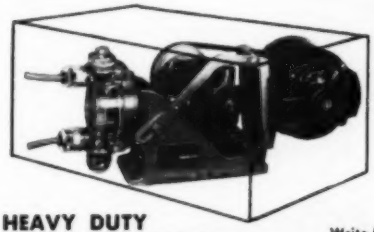


AUTOMATIC, PROPORTIONAL CHEM-O-FEEDER

0 to 5 GPH 4 to 100 psig.

Write for Bulletin SAN-6

For small and medium water and sewage works such as villages, towns, resorts, hotels, etc.



HEAVY DUTY MIDGET CHLOR-O-FEEDER

0 to 7 GPH 0 to 85 psig.

Write for Bulletin 1201-1

High degree of water filtration for swim pools, small towns, bottling plants, mills, etc.

PUR-O-CEL DIATOMITE FILTERS

30 different models
Complete "packaged" systems

Write for Bulletin 1800

%Proportioneers, Inc.% offers "packaged" units for water and sewage treatment. These packages may include all accessories comprising tanks, piping, fittings, control devices, and any other item to complete the installation. The furnishing of all integrated components assures you a properly engineered job and relieves you of responsibility for accessory purchases. Furthermore, %Proportioneers% packages are standardized and engineered for easy installation and maintenance, and for low first cost. Replacement parts are immediately available from local stock.

%Proportioneers% Equipment is used in water hypochlorination, fluoridation, general chemical feeding, sewage and industrial wastes treatment, chlorine dioxide treatment, and municipal water filtration.

%Proportioneers% Equipment is widely accredited because it does its job efficiently, accurately, easily . . . because %Proportioneers% units are "packaged" units — easy to install, easy to operate, low in first cost, low in upkeep cost.

May we help you with your chemical feeding problems? Write for data and recommendations.

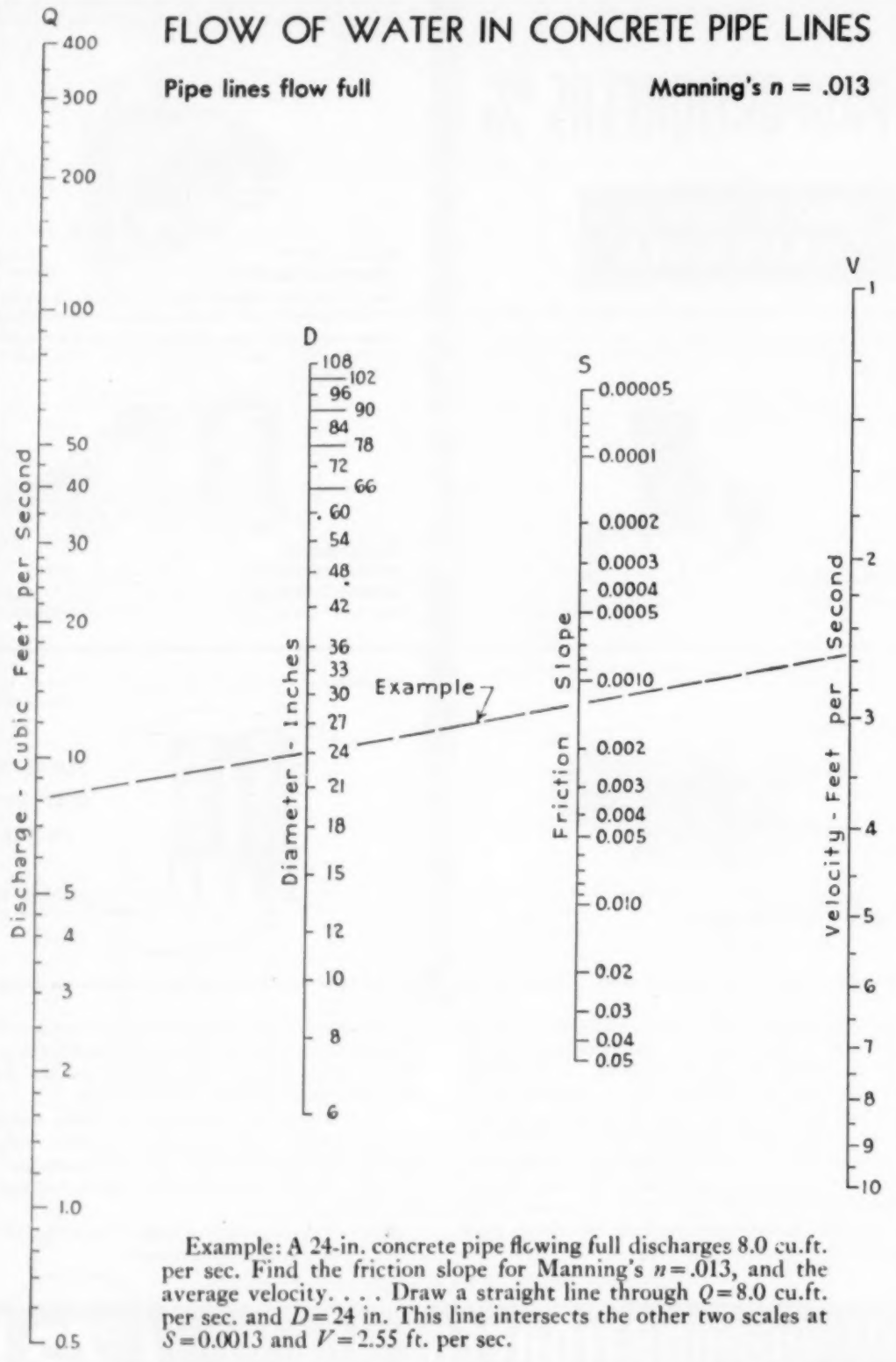
%Proportioneers, Inc.% 376 Harris Ave., Providence 1, R. I.

% PROPORTIONEERS, INC. %

Representatives in principal cities of United States, Canada, Mexico, and foreign countries

FLOW OF WATER IN CONCRETE PIPE LINES

Pipe lines flow full **Manning's n = .013**



Example: A 24-in. concrete pipe flowing full discharges 8.0 cu.ft. per sec. Find the friction slope for Manning's n=.013, and the average velocity. . . . Draw a straight line through Q=8.0 cu.ft. per sec. and D=24 in. This line intersects the other two scales at S=0.0013 and V=2.55 ft. per sec.

A chart constructed by Dr. F. T. Mavis, head Dept. of Civil Engineering, Penna. State College and appearing with the chapter "Flow of Water In Pipe Lines" by Professor J. E. Christiansen, University of California, written for "Concrete Pipe Lines," published by the American Concrete Pipe Association, 1942.

THE WELSBACH CORPORATION, *Kitson Valve Division*
1500 Walnut Street, Philadelphia 2, Pa. • Kingsley 5-4020

WELSBACH

WATER SERVICE PRODUCTS

.....with permanent

- **QUALITY**
- **ECONOMY**
- **DEPENDABILITY**

...built-right-in!

Including

Corporation Tapping Machines
Curb Stops
Corporation Stops
Couplings
Fittings and Unions
Brass Plugs
Meter Couplings
Ground Key Stops for General Service

for precision-built water service bronze... specify "WELSBACH-Kitson"

ALL PRODUCTS CONFORM TO A.W.W.A. STANDARDS

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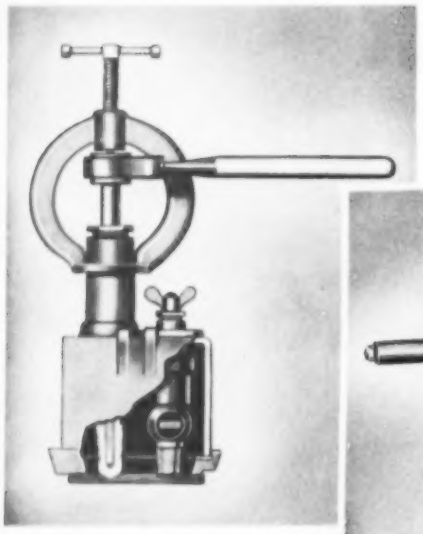
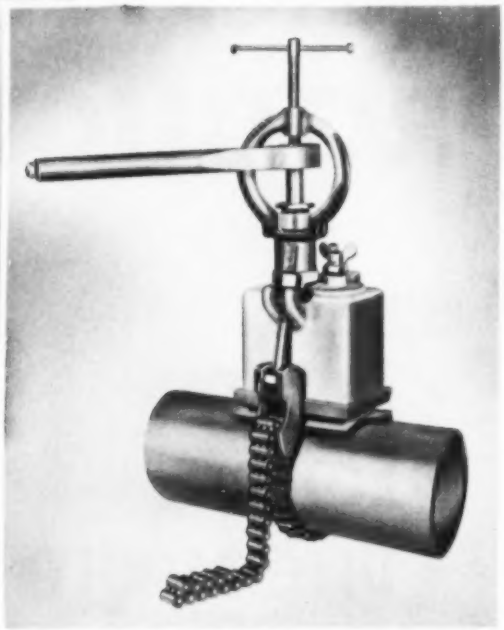
WELSBACH

The WELSBACH-*Kitson* CORPORATION TAPPING MACHINE



Sectional View of Machine Ready to Make Tap.



View of Machine Attached to Pipe Ready to Make Tap.

For installing corporation stops under pressure, this is the safest, surest, most easily-handled and, without sacrifice of inherent strength, the lightest corporation tapping machine ever made. It is so compact that it is ideal for making taps where space is limited.

It is the new Welsbach-Kitson Corporation Tapping Machine—an improved model of the popular Smith-Shelly Tapping Machine, equipped now with a flat chain and adaptor that provides positive non-slip pipe-gripping action . . . which makes it an even better machine than before. And in keeping with the simplicity of operation of this popular machine, the new adaptor which gives positive grip to the chain is easy to set and helps speed the operation.

No. 1 Machine. Makes ½", ⅜", ¾" and 1" insertions. Standard equipment furnished includes one each of ¾" and 1" A. W. W. A. thread combined drills and taps for cast iron pipe; one each of saddles in the following sizes: 4", 6", 8", 10", 12"; and chain in length suitable for 12" pipe . . . all packed in a specially constructed wooden chest.

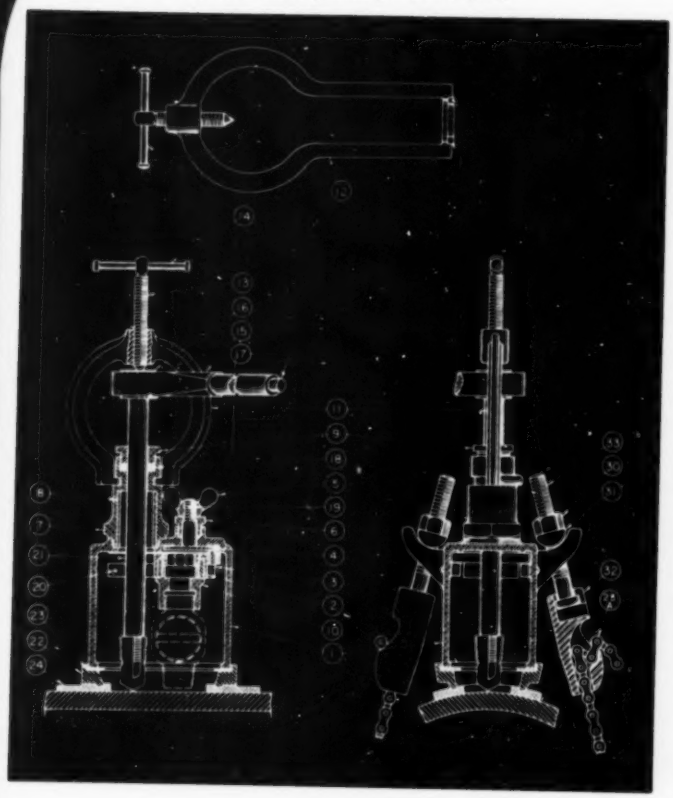
No. 3 Machine. Makes 1¼", 1½" and 2" insertions. Standard equipment furnished includes one each of 1½" and 2" A. W. W. A. thread combined drills and taps for cast iron pipe; one each of saddles in the following sizes: 6", 8", 10", 12", 16"; and chain in length suitable for 16" pipe . . . all packed in a specially constructed wooden chest.

Other types and sizes of combined drills and taps, saddles and longer chains for larger pipe may be specified as desired for either the No. 1 or No. 3 machine. Write the Welsbach Corporation, Kitson Valve Division for further information on special parts available.

THE WELSBACH CORPORATION, *Kitson Valve Division*
1500 Walnut Street, Philadelphia 2, Pa. • KIngsley 5-4020

WHEN ORDERING PARTS: For proper identification, use number and name of part shown on sectional drawing and parts list below. Owners of Smith Tapping Machines can modernize them by ordering and installing Welsbach's complete new chain assembly (parts No. 25A, No. 30, No. 31, No. 32 and No. 33) to give greater stability and more positive gripping action on the pipe being tapped.

Sectional drawing showing numbered parts.



List of parts for
Corporation Tapping Machines.

NO	NAME OF PART	MATERIAL	NO REQ	REMARKS
1	BODY	BRONZE	1	
2	CARRIER HOLDER	BRONZE	1	
3	SLIDE RAILS	BRONZE	2	
4	TRAVEL PIECE	BRONZE	1	
5	WING NUT	BRONZE	1	
6	STUFFING BOX FOR TRAVEL PIECE	BRONZE	1	
7	TOP	BRONZE	1	
8	TOP BUSHING	BRONZE	1	
9	TOP STUFFING BOX NUT	BRONZE	1	
10	CARRIER (COMPLETE)	BRONZE		
11	SMALL YOKE	MAL IRON	1	
12	LARGE YOKE	MAL IRON	1	
13	FEED SCREW	STEEL	1	
14	FEED SCREW HANDLE	STEEL	1	
15	RATCHET HANDLE	MAL IRON	1	
16	RATCHET WHEEL	STEEL	1	
17	RATCHET REVERSING PIN	STEEL	1	
18	TOP WASHER	RUBBER	1	
19	WING NUT PIN	BRONZE	1	
20	SLIDE RAIL SCREW	BRASS	4	
21	COMBINED DRILL AND TAP	STEEL		
22	SADDLE	BRONZE		
23	MACHINE GASKET	RUBBER	1	GASKETS ARE LEATHER ON ➡5 MACHINE
24	PIPE GASKET	RUBBER	1	
25A	CHAIN	STEEL	1	
30	CHAIN BOLT NUT	STEEL	2	
31	CHAIN BOLT ADJUSTER	STEEL	2	
32	CHAIN ADAPTOR	STEEL	2	
33	CHAIN BOLT	STEEL	2	

DIRECTIONS FOR OPERATING

(See sectional drawing above showing numbered parts.)

The corporation stop is screwed into the carrier (No. 10) which is then placed in the carrier holder (No. 2). The tap (No. 21) is put in place and the machine is then attached to the main as shown in the illustration on Page 2.

During the first operation of drilling and tapping the main, the feed should be continued until the face of the ratchet wrench is brought into contact with the gland (No. 9). The hole will than have been tapped to the standard size of pipe connection to be made. The yoke is then removed and the tap unscrewed until it is disengaged from the pipe. The drill shaft is pulled up as far as possible. The wing nut (No. 5) is turned half a revolution bringing the corporation stop into position for insertion. The drill is pushed downward to engage the carrier, and the stop is screwed into the main.

SHIPPING DIMENSIONS

No. 1—18¼" x 11¼" x 10½" equals 1.24 cu. ft. Completely boxed for shipment, weighs 90 lbs.

No. 3—27" x 17" x 16" equals 4.25 cu. ft. Completely boxed for shipment, weighs 220 lbs.

THE WELSBACH CORPORATION, *Kitson Valve Division*
1500 Walnut Street, Philadelphia 2, Pa. • Kingsley 5-4020

WELSBACH

CURB STOPS

Inverted Plug—Round Way

Iron Pipe Service

No. 1100 (illustrated) Stop, Combined Cap and Tee

No. 1101 (not illustrated) Stop and Drain, Combined Cap and Tee

No. 1102 (not illustrated) Stop, Separate Cap and Tee

No. 1103 (not illustrated) Stop and Drain, Separate Cap and Tee

Sizes ¾", 1", 1¼", 1½", 2"

Copper Inlet x Female Iron Pipe Outlet

No. 1110 (illustrated) Stop, Combined Cap and Tee

No. 1111 (not illustrated) Stop and Drain, Combined Cap and Tee

No. 1112 (not illustrated) Stop, Separate Cap and Tee

No. 1113 (not illustrated) Stop and Drain, Separate Cap and Tee

Sizes ¾", 1", 1¼", 1½", 2"

Copper x Copper Service

No. 1120 (illustrated) Stop, Combined Cap and Tee

No. 1121 (not illustrated) Stop and Drain, Combined Cap and Tee

No. 1122 (not illustrated) Stop, Separate Cap and Tee

No. 1123 (not illustrated) Stop and Drain, Separate Cap and Tee

Sizes ¾", 1", 1¼", 1½", 2"

HEAVY WALL STRUCTURE FOR EXTRA LONG LIFE

CURB STOPS

Minneapolis Pattern—Inverted Plug—Round Way

Iron Pipe Service

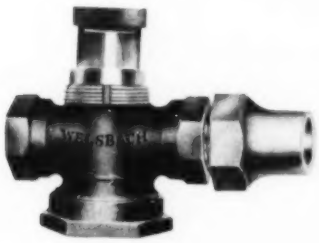
No. 1104 (illustrated) Stop, Combined Cap and Tee

No. 1105 (not illustrated) Stop and Drain, Combined Cap and Tee

No. 1106 (not illustrated) Stop, Separate Cap and Tee

No. 1107 (not illustrated) Stop and Drain, Separate Cap and Tee

Sizes ¾", 1", 1¼"



Copper Inlet x Female Iron Pipe Outlet

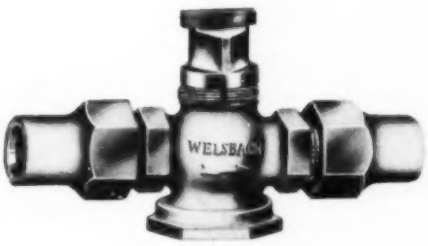
No. 1114 (illustrated) Stop, Combined Cap and Tee

No. 1115 (not illustrated) Stop and Drain, Combined Cap and Tee

No. 1116 (not illustrated) Stop, Separate Cap and Tee

No. 1117 (not illustrated) Stop and Drain, Separate Cap and Tee

Sizes ¾", 1", 1¼"



Copper x Copper Service

No. 1124 (illustrated) Stop, Combined Cap and Tee

No. 1125 (not illustrated) Stop and Drain, Combined Cap and Tee

No. 1126 (not illustrated) Stop, Separate Cap and Tee

No. 1127 (not illustrated) Stop and Drain, Separate Cap and Tee

Sizes ¾", 1", 1¼"

Note: For Minneapolis pattern, curb box thread is iron pipe size as follows:

Curb Stop Size	Curb Box Thread
¾"	1½"
1"	2"
1¼"	2½"

CURB STOPS

Round Way — Solid Tee Head

Iron Pipe Service

No. 1150 (illustrated) Stop
No. 1151 (not illustrated) Stop and Drain
Sizes ½", ¾", 1", 1¼", 1½", 2"

Copper Inlet x Female Iron Pipe Outlet

No. 1160 (illustrated) Stop
No. 1161 (not illustrated) Stop and Drain
Sizes ¾", 1", 1¼"

Copper x Copper Service

No. 1170 (illustrated) Stop
No. 1171 (not illustrated) Stop and Drain
Sizes ¾", 1", 1¼"

For Wiped Lead Connection x Female Iron Pipe

No. 1180 (illustrated) Stop
No. 1181 (not illustrated) Stop and Drain
Sizes ⅝", ¾", 1", 1¼", 1½", 2"

CURB STOPS — TO SPECIAL ORDER

We manufacture to special order Curb Stops in sizes other than those listed in this catalog. We also will manufacture to special order many other types not shown in this catalog such as Stops for wiped and flanged lead connections, and Round Way Curb Stops made to Newport, "H", and other non-standard patterns. Price and delivery information on special items can be obtained by writing to The Welsbach Corporation.

Important. Minimum quantities on orders for special Curb Stops are as follows:

Size—Inches	*Minimum Quantity*
½	200
⅝	200
¾	150
1	100
1¼	75
1½	50
2	25

In accordance with standard trade practice, the right is reserved on special orders to ship 10% over or under the quantity ordered.

CORPORATION STOPS

Copper Service—A.W.W.A. Standard Thread

No. 1200 (illustrated) Inlet A.W.W.A. Standard Thread; Outlet Copper, A.W.W.A. Standard, complete with straight coupling nut.

Sizes ¾", 1", 1¼", 1½", 2"

No. 1202 (not illustrated) Same as No. 1200, but with No. 1301 ⅛-bend coupling and gasket.

Sizes ¾", 1", 1¼", 1½", 2"

No. 1204 (not illustrated) Same as No. 1200, but with No. 1302 ¼-bend coupling and gasket.

Sizes ¾", 1", 1¼", 1½", 2"

For separate coupling nuts, bends, and gaskets, see page 8.

Corporation Stops with inlet iron pipe thread, outlet copper coupling, can be had on special order.

No. 1200 Corporation Stops usually are not tapped for male carrier thread, but can be so tapped on special order.

FOR WIPED LEAD CONNECTIONS

No. 1210 (illustrated) Inlet A.W.W.A. Standard Thread; Outlet Mueller; Tapped for male screw plug.

Sizes ¾", 1"

For larger sizes, refer to No. 1230

For couplings and bends, see page 8.

No. 1210 can also be furnished on special order with inlet iron pipe thread.

FOR INCREASED SIZE IRON PIPE OUTLET

No. 1230 (illustrated) Inlet A.W.W.A. Standard Thread; Outlet increased iron pipe size (one size larger than listed stop size); Tapped for male screw plug.

Sizes ¾", 1", 1¼", 1½", 2"

For couplings and bends, see page 8.

No. 1230 can also be furnished on special order with inlet iron pipe thread.

CORPORATION STOPS—TO SPECIAL ORDER

We manufacture to special order Corporation Stops of many non-standard types, with a wide variety of inlet and outlet thread combinations. We also manufacture to special order non-illustrated sizes of standard Corporation Stops and Corporation Stops with inlet iron pipe thread in place of A.W.W.A. standard thread.

Important: Minimum quantities on orders for special Corporation Stops are as follows:

Size—Inches	*Minimum Quantity*
½	200
⅝	200
¾	150
1	100
1¼	75
1½	50
2	25

In accordance with standard trade practice, the right is reserved on special orders to ship 10% over or under the quantity ordered.

WELSBACH

COUPLINGS

A. W. W. A. Standard Thread — for Copper Service

No. 1300 (illustrated) Straight Coupling (does not require a gasket)

Sizes ¾", 1", 1¼", 1½", 2"

No. 1301 (illustrated) ⅛-bend

Sizes ¾", 1", 1¼", 1½", 2"

No. 1302 (not illustrated) ¼-bend.

Sizes ¾", 1", 1¼", 1½", 2"

No. 1305 (not illustrated) Copper Asbestos Gasket.

Sizes ¾" 1", 1¼", 1½", 2"

Adaptor Couplings—for Nos. 1210 and 1230 Corporation Stops and Copper Service

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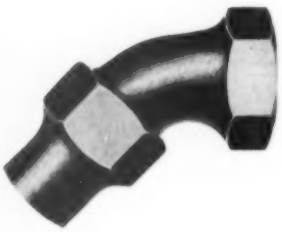


No. 1321 (illustrated) To adapt from Mueller outlet thread to copper service, ⅛-bend.

Sizes ¾", 1"

No. 1331 (not illustrated) To adapt from increasing size iron pipe outlet thread to copper service, ⅛-bend.

Sizes ¾", 1", 1¼"

No. 1322 (illustrated) To adapt from Mueller outlet thread to copper service, ¼-bend.

Sizes ¾", 1

No. 1332 (not illustrated) To adapt from increasing size iron pipe outlet thread to copper service, ¼-bend.

Sizes ¾", 1", 1¼"

Gaskets are supplied with all couplings except No. 1300.

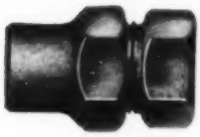
THE WELSBACH CORPORATION, *Kitson Valve Division*
1500 Walnut Street, Philadelphia 2, Pa. • Kingsley 5-4020

WELSBACH

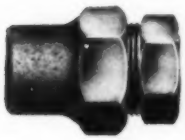
FITTINGS AND UNIONS

for Copper Service

No. 1310 (illustrated) Copper to male iron pipe.
Sizes ¾", 1", 1¼", 1½", 2"



No. 1311 (illustrated) Copper to female iron pipe.
Sizes ¾", 1", 1¼", 1½", 2"



No. 1312 (illustrated) Two-part Copper Union.
Sizes ¾", 1", 1¼", 1½", 2"

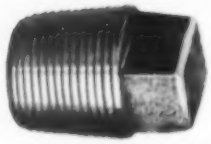
No. 1313 (illustrated) Three-part Copper Union.
Sizes ¾", 1"

No. 1314 (illustrated) ¼-bend Copper by male iron pipe.
Sizes ¾", 1", 1¼", 1½", 2"

ALL PRODUCTS GUARANTEED

WELSBACH

BRASS PLUGS



No. 1350 (illustrated) Brass Plug, A.W.W.A. Standard thread for dry connection.

Sizes ¾", 1", 1¼", 1½", 2"

METER COUPLINGS—*To Special Order*

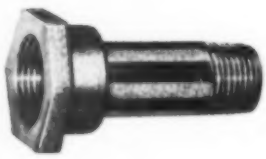
Meter Couplings are manufactured to special order only in the following minimum quantities:

Coupling Size	For Meter Sizes	Quantity
⅝	½ & ⅝	200
¾	⅝ x ¾ & ¾	150
1	1	100

Meter Couplings are furnished with leather washers and with nuts not drilled unless otherwise specified.

No. 1360 (illustrated) Plain straight Meter Coupling, Machine Finished

No. 1362 (illustrated) ¼-bend Meter Coupling, Rough Finished



No. 1365 (illustrated) Ribbed straight Meter Coupling, Rough Finished

THE WELSBACH CORPORATION, *Kitson Valve Division*
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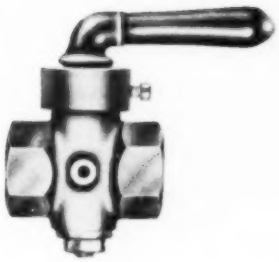
WELSBACH

GROUND KEY STOPS FOR GENERAL SERVICE

Cap Pattern — Flat Way — Adjustable Handle



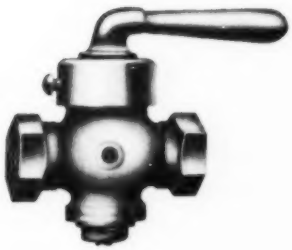
No. 1400 (not illustrated) Lever Handle Stop
Sizes ½", ¾", 1", 1¼"

No. 1401 (illustrated) Lever Handle Stop and Drain
Sizes ½", ¾", 1", 1¼", 1½", 2"

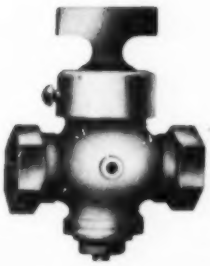
No. 1402 (not illustrated) Tee Handle Stop
Sizes ½", ¾", 1", 1¼"

No. 1403 (illustrated) Tee Handle Stop and Drain
Sizes ½", ¾", 1", 1¼", 1½", 2"

Cap Pattern — Round Way — Adjustable Handle



No. 1405 (illustrated) Lever Handle Stop and Drain
Sizes ½", ¾", 1"



No. 1407 (illustrated) Tee Handle Stop and Drain
Sizes ½", ¾", 1"

EACH PLUG INDIVIDUALLY FITTED TO ITS OWN BODY

WELSBACH

GROUND KEY STOPS FOR GENERAL SERVICE

Rough Pattern—Flat Way—Solid Handle

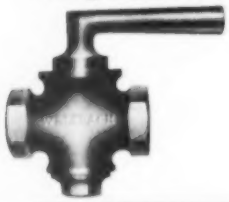
No. 1410 (illustrated) Tee Handle Stop
Sizes ¼", ⅜", ½", ¾", 1", 1¼", 1½", 2"

No. 1411 (not illustrated) Tee Handle Stop and Drain
Sizes ½", ¾", 1", 1¼", 1½", 2"

No. 1412 (illustrated) Lever Handle Stop
Sizes ¼", ⅜", ½", ¾", 1", 1¼", 1½", 2"

No. 1413 (not illustrated) Lever Handle Stop and Drain
Sizes ½", ¾", 1", 1¼", 1½", 2"

Rough Pattern—Round Way—Solid Handle



No. 1415 (illustrated) Lever Handle Stop

No. 1416 (not illustrated) Lever Handle Stop and Drain
Sizes ½", ¾", 1"

Bend Hydrant—Solid Tee Handle

No. 1420 (illustrated) Stop and Waste
Sizes ½", ¾", 1"

Solid Lever Handle Bibb

No. 1500 (illustrated) Plain Bibb
Sizes ¼", ⅜", ½", ¾"

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a common point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

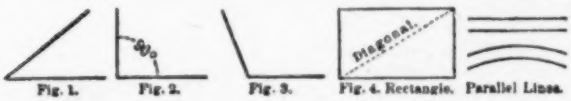


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

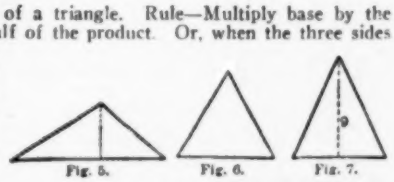


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

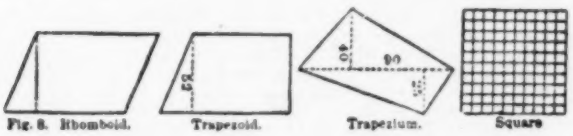


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

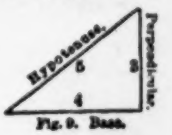


Fig. 9.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

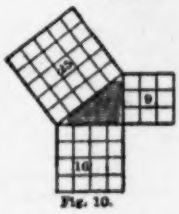


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base) = 16; of 3 (perpendicular) = 9; the square root of their sum (25) = 5, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Answer—45 rods.

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be ($\sqrt{4000} = 63.246$) 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

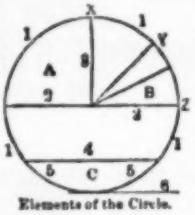
$35 \times 10 = 350$,
1% of 350 = 3.5
7)346.5
Ans. (rd.) 49.5

This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

The Circle

A circle is a plane figure bounded by a curved line, (1. 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—$28 \times 3\,1/7 = 88$ in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—$144.5 \times .3183 = 46$ in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—$20^2 \times .7854 = 314.16$ sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—$50^2 \times 3.1416 = 7854$ sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, $43560 \times .3183 = 13865$; $\sqrt{13865} = 117\frac{3}{4}$ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.

The diameter of a log is 24 inches; how large a sill can be cut from it?

$24 \times .707 = 17$ in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—$12 \times 1.414 = 17$ in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—$20 \times 80 = 1600 \times .7854 = 1256.64$ sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—$50 \times .464 = 23.2$ in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

$(41 + 29) = 70 \times 3.1416 \div 2 = 110$ ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

$60 \times 40 = 2400 \times .7854 = 1885$ sq. ft. nearly.

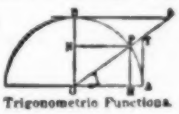
Polygons

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

$30^2 \times .433 = 389.7$ in. T; $10^2 \times 4.824 = 482.84$ in. O.


Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A, versed sine
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—$12^2 \times 6 = 864$.

How many cubic in. in a cubic foot?

Answer—$^{\bullet}12^3 = 1728$.

Find cu. ft. in a cu. mile.

Answer—$5280^3 = 147197952000$.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—$10\frac{1}{2} \times 3 \times 1\frac{1}{4} = 39\frac{3}{8}$.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

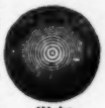
$10^2 \times .433 \times 2 = 86.6$ sq. in. in area of the two ends.

$10 \times 25 \times 3 = 750$ sq. in. area of sides. $86.0 + 750 = 836.6$.

How many cubic inches in above prism, 10 by 25 inches?

Answer—$10^2 \times .433 = 43.3 \times 25 = 1082\frac{1}{2}$ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.


Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone. Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

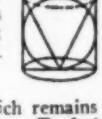
Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.



The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$ area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

3)549(183, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

CUBIC FEET, GALLONS, POUNDS, AND TONS OF WATER IN RECTANGULAR TANKS*

THIS chart will be found useful for rectangular tank determinations. The dimensions of the tank, all in inches, are given in columns A, C, and D. Then, as will be noted, you can find the number of cubic feet in column E, the gallons in column F, the pounds of water in column G, and the tons of water in column H. As a typical example, let us say that the width of a given tank is 10 inches, the depth 5 inches, and the length 20 inches. How many pounds of water will the tank hold?

How to Use the Chart

Find the 10 in column A and run a straight line over to the 5 in column C and locate the intersection with column B. Then from that point of intersection run over to the 20 in column D, and note the intersection with column C. It will be observed now that column C and J are exactly alike so that perfectly horizontal lines can be drawn between those two columns. In this instance the intersection in column C happens to be through the 10, so simply run a straight line through the 10 in column C and the 10 in column J, as shown by the dotted line, and you have a perfectly horizontal line which gives all of the answers as follows:

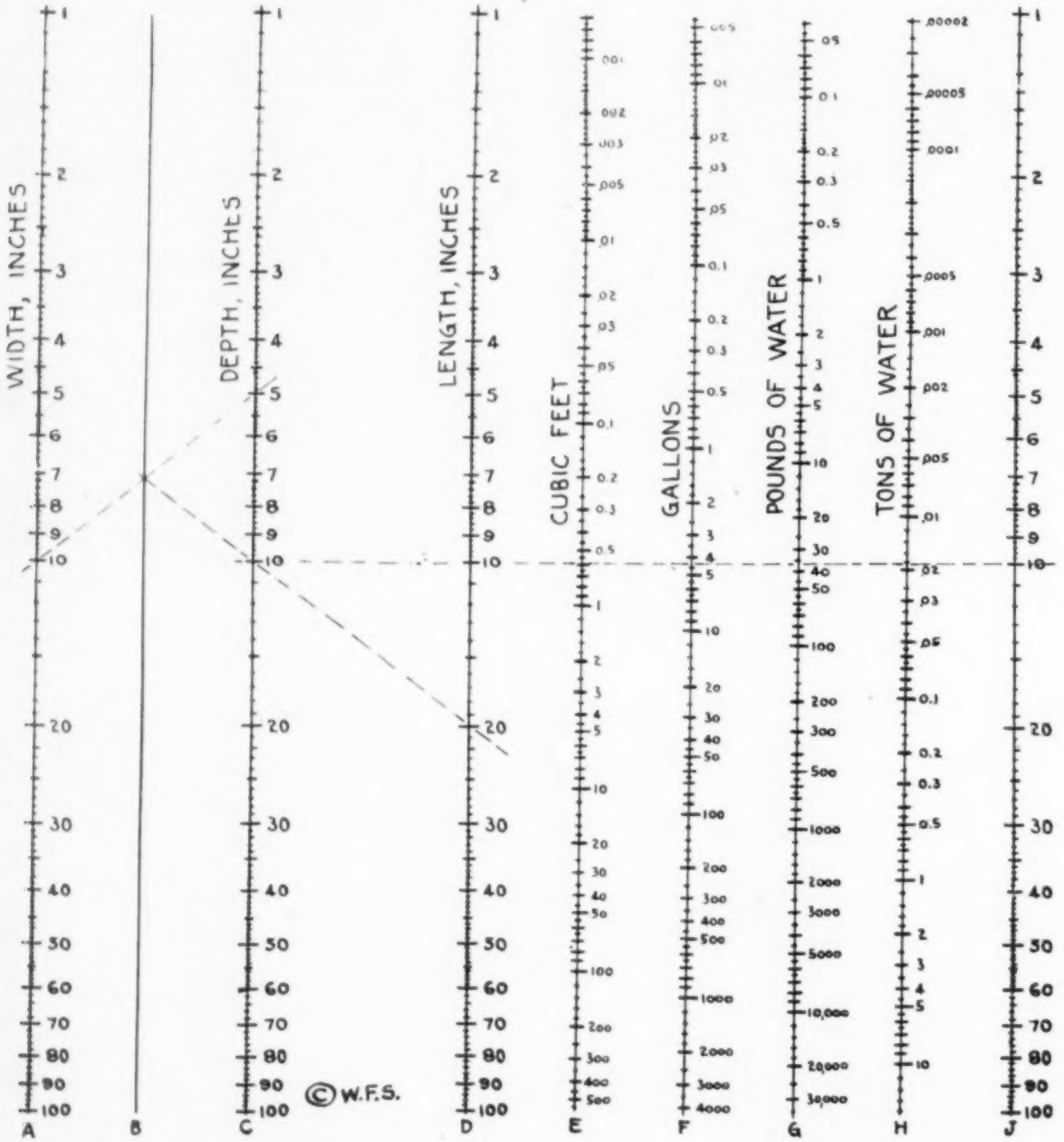
Column E shows that the tank has a volume of nearly 0.6 cu. ft.

Column F shows that the number of gallons is about 4.3.

Column G shows that if the tank contains water the weight will be about 37 pounds.

Column H shows that the number of tons of water is approximately .0185.

*Contributed by W. F. Schaphorst, M.E., Newark, N. J.



EXPERIENCE IN SEWER MAINTENANCE*

By W. H. WISELY

Exec. Secy. and Editor, Federation of Sewage and Industrial Wastes Assns.

THE most important equipment in sewer department is a master map of the system, supplemented by larger scale sectional maps on which are shown important details such as direction of flow, exact manhole locations, sewer sizes and slopes, house connections, etc. Phelps (San Diego) has found that good maps save time and minimize damage to streets and private property, and recommends that all extensions to the system be plotted as made so that the reference maps will always be up-to-date. At Rockville Center, N.Y., Anderson[1] keeps a card index for permanent notes and a log book for daily maintenance notes, both of which are indexed to the sectional maps. The log book is kept by the field crew and records the location of work, conditions found, equipment used and daily costs.

Practice as regards frequency of routine inspection varies widely. Several contributors report that inspections are made only as difficulty arises, while others confine routine inspection to those sewers which have given trouble previously. A number of those reporting this inspection practice indicate that lack of personnel obviates a regular schedule.

Most general inspection practice appears to be as follows: sewers on flat grades or previously troubled by roots—every three months; sewers in which no trouble has been recorded—once to twice yearly; main intercepting sewers—one to four times per month; flush tanks—every month; inverted siphons—one to four times monthly; storm water overflows—during and following heavy rains. Some larger cities maintain a trained inspection crew which is continuously engaged in following a prepared schedule.

Anderson[1] warns that a casual glance into the manhole does not constitute adequate inspection. Steelman (Ocean City) advises inspection of critical sections during peak flows, which advice is substantiated by experience at Urbana-Champaign, Ill., where an 18-inch interceptor appeared to be flowing freely during numerous dry weather observations but was found to be carrying only 25 per cent of capacity when surcharged at the upper end during a very wet season, due to an unusually bad root condition. "Lamping" a section, by looking through the sewer during low flows toward a flashlight (explosion proof) held at the next manhole, is a common method of inspecting lines of 12-inch diameter and larger. Superintendent Case (Merchantville-Pennsauken, N.J.) employs an inspection crew of three men who ascertain the condition of the line by observation at the lower manhole while the line is being flushed or probed with light rods. A change in the color or solids content of the flow will indicate an accumulation. At Birmingham, Mich., the condition of lateral sewers is ascertained whenever an opening is made for a new house service connection.

Where a program of routine cleaning "whether they need it or not" is possible, it is usually correlated with the inspection schedule. At Cimarron, Kan., City Engineer R. R. Crusinberry has developed a schedule of routine cleaning that enables coverage of the entire system every year. At Rockville Centre, where there are 78 miles of sewers, Anderson[1] has planned to clean 26 miles of sewer each year, thus covering the entire system every three years. The work is carried out from March 15 to July 1 and from September to November, totalling about 150 days of the most suitable weather. Work in the business district is done between 4 a.m. and noon to avoid heavy traffic. A similar 3-year schedule for cleaning trunk line sewers, involving work on about 33 miles of sewer per year, has been developed by Superintendent George D. Carpenter at Ithaca, N.Y.

Baltimore, Md., has a well organized plan for continuously servicing the 1,900 miles of sewers and drains in that city.[2] Five crews of three men each are assigned to definite territories and are equipped to clean street inlets and manholes, approximately 1,200 to 1,500 being cleaned weekly. Four crews of five men each are equipped for servicing house connections and small laterals and are constantly engaged in this work. One six-man crew is equipped to work on large sewers and drains. The plan affords continuous maintenance, minimizing complaints and inconvenience to property owners.

Twenty-nine well equipped field crews are able to completely cover the 2,800 miles of sewers in Los Angeles, Cal., twice each year by working according to a systematic plan.[3]

Any routine sewer cleaning program must be arranged to allow for interruptions for emergency calls.

Fig. 1—Full bucket raised by Turbine sewer machine.

Sewer Maintenance Equipment

The size and type of sewers to be serviced, of course, determine largely the nature of equipment required, but certain items are essential to any efficient crew. Sanitary sewers will usually be troubled mostly by roots and grease, while combined or storm sewers will nearly always accumulate grit and are most likely to receive miscellaneous debris. The equipment carried by the maintenance crew will be most adapted to the character of stoppages anticipated but there must also be equipment for handling the unexpected.

A typical list of essential equipment carried by a full-time, large city maintenance crew working on all types of sewers has been developed from data furnished by the contributors to this article:

Major Equipment

- 2½ ton truck
- Power winch
- Portable, manually-operated winch
- 1,000 feet flexible steel cable
- 1,000 feet fire hose
- 600-800 feet flexible rods (power drive desirable)
- 500 feet interlocking wood sewer rods
- Root cutters of assorted sizes
- Sewer brushes of assorted sizes
- Sand buckets, scoops and drags of assorted sizes
- Turbine flushing heads
- Steel sewer tapes and heavy wire (for small sewers)
- Sewer flushing bags

Minor Equipment

- Shovels, picks and mattocks
- Assorted wrenches
- Hydrant and manhole tools
- Flash lights (explosion proof)
- Rubber boots, coats and gloves
- Buckets and rope

Safety Equipment*

*A combination combustible gas indicator, oxygen deficiency lamp, and toxic gas detector is available on the market.

- Hydrogen sulfide detector
- Carbon monoxide detector
- Combustible gas indicator
- Wolf safety mask
- Hose mask (double) with safety harness
- Safety belts (2 or 3)

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(Note: Several of the original illustrations have been replaced by photographs of newer sewer cleaning equipment.—Ed.)

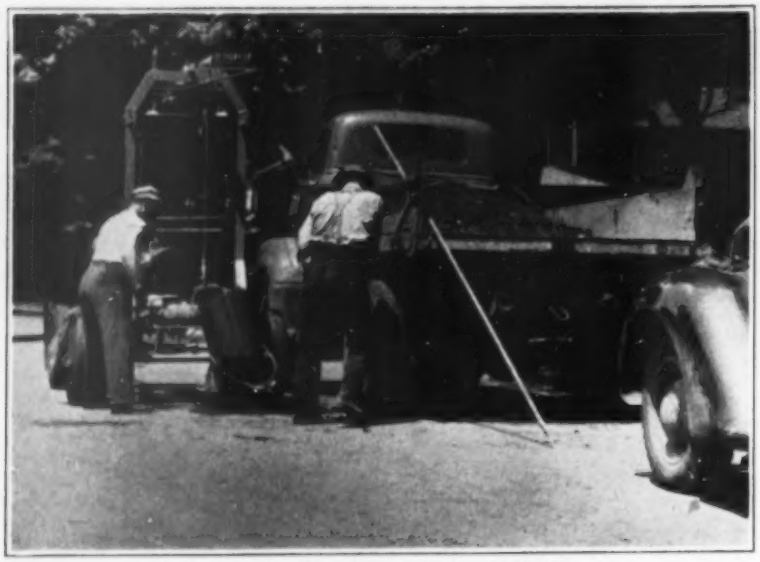

Fig. 2—Champion sewer cleaning equipment.

Complete first aid kit
Manhole guard rails
Traffic signs and flags
Oil lamps and flares

Commenting on the above list, the power winch for pulling scoops, brushes or buckets may be provided for in several ways. There are several excellent portable power units (Figs. 1, 2, 3) available, specifically designed for sewer cleaning, in which the engine, cable reel (with control clutch) and pulley frame are mounted on wheels and can be moved about as a trailer. At Champaign, Ill., the winch is mounted on the truck and is powered by the truck motor.

The sewer service crew of the Joint Meeting Sewer Commission of New Jersey is equipped with several unusual items which have proven highly useful.[8] A short-wave radio receiving set keeps the crew in contact with headquarters regardless of their location about the large area in which they must work; a portable platform derrick expedites heavy loading jobs and is used to transport the sewer cleaning winches; a portable, 1,500-watt generator supplies current for floodlights used in night work and for the portable air blower employed in ventilating sewers and manholes as a safety measure. Portable generators are also carried on some of the sewer maintenance trucks used at Los Angeles.

The sewer maintenance departments of cities of moderate and small size are seldom equipped as completely as listed above, despite the fact that the best of equipment yields greatest economy. Commonly, the general purpose city truck is used to transport loose equipment or pull a small trailer. The truck is sometimes used to pull scoops, drags or brushes as a substitute for more suitable power machines. There is also an unfortunate tendency for small city crews to work without adequate safety equipment and fatal accidents in such crews are much too common. Phelps (San Diego) suggests that the cooperation of the local gas company be obtained when special testing equipment is required for occasional gas surveys.

Character of Sewer Stoppages

The most common obstructions in sewers, in the order of greatest incidence, are (1) roots, (2) accumulations of grease, (3) grit and (4) miscellaneous debris.

Roots generally enter at faulty joints. Growth usually occurs from a single leader root which continues developing inside the sewer until branches from the leader often fill the entire pipe. Phelps reports one root growth 30 feet in length removed from a sewer in San Diego. Care in making joints, use of proper jointing materials and careful tamping of backfill during sewer construction are good insurance against root troubles later.

Copper, toxic to most plants, has been employed to control root growths. A copper ring, made for the purpose, is available for placing in the joint at the time the sewer is laid. Killing of root growths in sewers by copper sulfate is successfully practiced at San Diego, Cal., and Greenville, Tenn., and elsewhere, a handful of blue vitriol crystals being dropped into a manhole above the suspected root growth, while flow is taking place. Repeated applications may be necessary to kill the leader growth, which later break loose due to the water pressure behind it.

Superintendent Case of Merchantville, N.J., reports most root troubles caused by poplar and willow trees and these are removed where difficulty has been caused, to prevent recurrence.

Grease accumulations on the inside of the sewer and in the form of floating balls is a major problem at Atlantic City, N.J.,[8] and other places. Ordinarily discharged to the sewer with hot or warm water, the grease congeals as it cools and adheres to the walls of the sewer or develops into a ball with some small particle or object as a nucleus. These accumulations continue to build up until they materially reduce the capacity of the sewer.

Grit in the form of cinders, ashes, sand, mud, etc., which enters combined and storm sewers with surface water run-off and sanitary sewers with basement drainage, is often troublesome, particularly where sewers are on flat grades. At Rock Falls, Ill., and elsewhere, unpaved streets are the source of excessive grit deposits in sewers. Sewers laid through quicksand often shift due to the unstable foundation, opening at the joints and permitting the fine sand to enter. This condition is serious at East Aurora, N.Y., and, to a lesser extent, at Ocean City, N.J. Mud and sand originating at automobile wash racks is reported to be a cause of grit accumulation in sewers at Kahoka, Mo., and Cimarron, Kan.

The character of miscellaneous debris removed from sewers (combined and storm drains in particular) is almost unimaginable. Barrels, posts and a bed spring are on the list at Bloomington-Normal, Ill., and a washing machine was once removed from a large line at Springfield, Ill. Removal of some of these articles demands much ingenuity and patience on the part of sewer maintenance personnel.

Sewer Cleaning

Flushing.—Although not always positive, flushing of sewers is a convenient method of scouring out minor grit deposits and grease accumulations.

Surface water discharges during rains provide adequately for flushing storm and combined sewers, although supplementary flushing by fire hose is employed at Birmingham, Mich., Portland, Ore., and Sacramento, Cal., in conjunction with other cleaning operations, to clean lateral lines and to reduce odors at manholes in extended dry weather seasons. Routine flushing is a general practice in maintaining separate sanitary sewers but the frequencies reported vary from monthly to annually. At Orillia, Ontario, where the sanitary sewers have a minimum slope of 5 per cent, Engineer L. G. McNeice indicates that annual flushing is practically the only maintenance required. In some cases, as at Ithaca, N.Y., and Kahoka, Mo., routine flushing is limited to critical lines on flat grades, which are flushed every two or three weeks. At Kahoka, some shallow lines are flushed after midnight by means of a time-clock actuated electric valve on the water service, giving a discharge of twenty minutes' duration.

Many old sewer systems were equipped with automatic flush tanks, located at the upper ends of laterals to assure scouring of deposits. Present practice is to design sewers with adequate slopes and the use of such devices is confined to lines in which flat grades are unavoidable. A number of contributors to this article indicate that old flush tanks have been abandoned; others that they are still used occasionally.

From a practical study of the hydraulics of sewer flushing, Watson[6] concludes that the *depth* of the flushing flow in the sewer is equally as important as the velocity. This accounts for the fact that flushing is most effective when the sewer is plugged at the lower manhole, the fire hose used to loosen grit deposits and grease accumulations and, after a head of sewage and water is built up, the plug is suddenly removed to release the flush. Kilpatrick (Rollo, Mo.) emphasizes the importance of blocking the sewer in connection with flushing operations. Sewer "bags," having a hose connection at one end and a nozzle in the other, are available for plugging the sewer and adding flushing water at the same time.

Satisfactory flushing by means of "water wagons" is accomplished at Los Angeles[8] and Lower Merion Township, Pa.[10] In the latter case, water is discharged at the upper manhole from a 625-gallon steel tank mounted on a truck and having a 6-in. drain valve. Discharge is so rapid that an 8-in. sewer is completely filled, giving an effective flush of 500 to 800 feet of sewer.

Hydrogen sulfide formation in sewage is accelerated by the presence of septic sludge deposits in sewers. Bowlus[11] reports that sulfides are definitely reduced after flushing, indicating that the practice is beneficial in reducing odors at manholes and treatment works as well as in reducing damage to sewers and concrete structures.

Removal of Roots.—For cutting and removing root growths in sewers up to 15 in.

m diameter, flexible type rods and cutters appear to be very popular, because of the time saved, compactness of the equipment and small labor requirement. An auger-like cutter is used, which is rotated by twisting the rods as they are forced down the sewer. The equipment can be operated easily with two men if the power drive is used, or four men if the rods must be twisted manually. Another advantage of this equipment is that it can be fed into the sewer from ground level and does not require entry into manholes. Flexible sewer rods are illustrated in Figs. 5 and 6.

For removing roots from larger sewers, or particularly obstinate ones from small sewers, cutting drags are pulled through by cables and winches, either power or manually operated. (Fig. 4). This procedure is positively effective, and in many cities is the only method used.

At Ocean City and Merchantville, N.J., every effort is made to prevent recurrence of root growths which are removed from sewers. Steelman at Ocean City reports that defective joints admitting roots are immediately located and repaired and some very troublesome lines have been relaid in iron pipe. Poplar and willow trees causing trouble at Merchantville are removed. Permanent control of roots in house service lines is the aim at Birmingham, Mich., where the city provides 6-in. cast iron pipe with leaded joints to the property line and requires not less than vitrified pipe with asphalt mastic joints inside the property. In case of root stoppage in old cement jointed vitrified pipe services (in the street), the city relays the service to the property line in cast iron pipe for a permit fee of $15.00.

Removal of Sand and Grit Deposits.—When flushing does not produce adequate results, sand buckets or scoops pulled through by the cable and winch outfit are universally depended upon for removing deposits of grit. This equipment (Fig. 1) is positive in effectiveness, regardless of the size of the accumulation.

Where the deposit is not too large, the "Turbine" cleaner which has a water powered, rotating cutter is effective. This device, dragged through the sewer by cable and winch, combines water jet flushing, cutting and dragging into one effective operation.

Rawn[7] describes an ingenious sewer "hoe" used by the Los Angeles County Sanitation Districts for removing grit accumulations from sewers over 30 in. in diameter with a minimum of labor. The device is propelled through the sewer by the pressure of sewage behind it and the invert and sides of the pipe are scoured as it moves. For sewers of 15 to 30 in. in diameter, a beach ball inflated to approximately the size of the sewer is used effectively in the same fashion as the "hoe."

Removal of Grease Accumulations.—Unless of industrial origin, sewer stoppages by grease are confined almost entirely to house services; however, the capacity of larger sewers is often reduced due to the development of a grease lining in the pipe.

Flat sewer tapes with various kinds of cleaning tools are used for removing grease obstructions from house connections at Ocean City, N.J. Large sewers give no trouble here. At Atlantic City, N.J.,[8] the most useful device for opening house connections has been found to be a 50-ft. length of quarter-inch steel wire. The end started into the sewer has a 6-in. bend which is rotated by cranking the other end as the wire is fed, thus gouging out the stoppage.

Grease accumulations in larger sewers are loosened to some extent by flushing, root-cutting and other maintenance operations. Sewer brushes, dragged through by the ever useful winch and cable equipment, are most positive, however, and many well-trained crews always use a brush drag to finish up a line that has been dragged with other tools.

Fig. 3—Salt Lake City, Utah, designed this special bucket. A double shift of employees can remove 175 cu. yd. of deposit per day.

Other Cleaning Devices.—It will be noted that certain types of equipment are best suited to specific cleaning problems, yet it may often be necessary to use practically all of the equipment carried for cleaning a single line. For instance, the flexible rod and root cutter and/or detachable wooden rods may be used to partially open a stoppage to permit a cable to be threaded through for use in dragging, and several types of drags may be employed. Unusual situations will often demand considerable thought and ingenuity on the part of the maintenance crew even though they are well equipped for ordinary problems.

The sewer "hoe" and beach ball cleaners described above are examples of such ingenuity. The Los Angeles County Sanitation Districts, where these labor-saving implements were devised, makes root cutting drags for 12 to 36-in. sewers from steel pipe[7]; sewer brushes at Ithaca, N.Y., are made from old street-sweeper brooms; a knot of old chain has been found to constitute a serviceable root cutter and drag at Portland, Ore.; a 15-in. root cutter was made to service an 18-in. sewer at Urbana-Champaign, Ill., by wrapping the periphery with barbed wire, further illustrating actual practice in meeting local problems.

Ground Water Infiltration

Although most ground water infiltration results from faulty sewer construction (poor joints or failure to use proper pipe through critical water-bearing soil formations), good maintenance and operation practices can reduce this problem. In referring to infiltration, nearly all of the contributors to this article mentioned the relatively new asphalt mastic jointing compounds as a curative measure, either in explaining why there was no serious infiltration problem or describing how it is being minimized in new extensions or old sewer repairs.

Where there is ample sewer capacity, gravity flow and no sewage treatment works, there is an inclination to disregard infiltration to some extent. Usually the allowance for infiltration in the design of separate sanitary sewers is only nominal but such leakage often proves to be of serious consequence, as at Ithaca, N.Y., where it amounts to 100 to 400 per cent of the dry weather sewage flow due to broken pipe and poor joints. Superintendent Carpenter indicates that correction can be accomplished only by replacement of the defective lines by cast iron or other suitable pipe.

Where sewage must be pumped, it has been found economical to locate and actually replace those lines admitting large amounts of ground water. This has been done at McHenry and Fox River Grove, Ill., Rolla, Mo., and elsewhere.

Fig. 4—Cutting drag pulled through sewer by Turbine machine.

Steelman (Ocean City, N.J.) and Bridges (Kahoka, Mo.) point out the necessity of careful control and inspection of house connections to minimize infiltration. The sharp increase in flow in sanitary sewers during rains is usually caused by illicit downspout connections which are most difficult to control since many of them are changed after the installation inspection is made. Constant vigilance, public education and rigid enforcement of ordinance provisions are the only possible means of minimizing this source of extraneous water. Kahoka, Mo., and Birmingham, Mich., sewer users are required to comply with strict specifications for workmanship and materials in constructing house sewers.

Maintenance of Appurtenant Sewerage Structures

Aside from ordinary inspection and replacement of broken manhole covers, it is important that manholes in unimproved or semi-permanent streets be maintained at the proper elevation. Considerable damage to such streets is done when an attempt is made to find a manhole which has been covered. Rattling manhole lids often create a nuisance and correction has been accomplished by: application of tar or asphalt around the entire rim or at three or four points[10]; gaskets of rubber, jute or canvas; machining of the lid and casting; use of mechanical locking lids or low center of gravity types. Anderson,[1] after trying several methods, now uses a tape packing made for the purpose which is placed around the entire periphery after thorough cleaning of the casting.

Other appurtenances common to separate sanitary sewers are inverted siphons, creek crossings and flush tanks. Inverted siphons must be inspected frequently as they are readily clogged by accumulations at the inlet or grit deposits in the siphon pipes. Two siphons on intercepting sewers at Champaign-Urbana, Ill., are inspected at least weekly and cleared of inlet accumulations. Three siphons at Ithaca, N.Y., are flushed out every four months. Creek crossing structures are generally checked following wet seasons to ascertain erosion damage, replace protecting rip-rap or make repairs. Flush tanks maintained in regular service are inspected monthly and afforded cleaning and adjustment.

Frequent cleaning of catch basins on storm or combined sewer systems is justified by the protection they provide against grit deposits in the sewers. Practice appears to be to clean these at least annually where paved streets are drained and more often when streets do not have a permanent surface. Street inlets are inspected and cleared after every rain at Rock Falls, Ill., to assure good street drainage. Storm water overflows are inspected and given necessary attention at least once monthly at Birmingham, Mich., and Bloomington, Ill., with more frequent attention being accorded in wet seasons. Sewage flow regulators and adjustable overflows in combined systems are best attended during high flows so that they may be adjusted to actual operating conditions.

Regulation of Use of Sewers

Probably no other public utility is misused to so great a degree as is the sewer system, yet there is always readiness on the part of the public to criticize faulty operation. This condition is no doubt largely due to the lack of public education and to the failure of city officials to adopt and *enforce* proper ordinances controlling the usage of sewers. Such an ordinance does no good if merely filed among the dusty archives of the municipality—it must set forth proper practices, contain adequate penalties and be enforced without hesitancy when courteous requests for cooperation are ignored.

Anderson[1] points out that the best way to obtain public cooperation is to definitely allocate responsibility for house sewer connections to the property owner, requiring him to pay for any maintenance work necessary on these lines. Many eastern cities have established a policy of accepting responsibility for all sewers outside the curb, which practice appears to have several advantages. The Atlantic City Sewerage Co.[5] requires a trap on each house service at the curb and responsibility in each case is determined by examination of the trap. The company services all sewers outside the curb and local plumbers perform at the property owner's expense any work needed from the curb to the house.

Among the more important items warranting inclusion in the sewer ordinance are:

1. Control over location of certain trees (poplar and willow) which might cause root stoppages, including authority to remove such trees found to cause trouble.

2. Prohibition of downspout and similar surface water connections from separate sanitary sewers.

3. Provision for detailed inspection by competent personnel of all house service installations. Also rigid specifications covering workmanship and material in house services.

4. Requirement of suitable preliminary treatment facilities in commercial and industrial concerns to prevent damage to sewers. Wastes commonly controlled for this purpose are: (a) Greasy wastes from restaurants, packing plants, etc.; (b) oil and dirt from automobile filling stations and wash racks; (c) Inflammable and explosive wastes from cleaning establishments; (d) wastes containing excessive solids, such as spent grain from breweries, paunch manure from packing plants, ashes, garbage, etc.; (e) corrosive wastes, as those from metal galvanizing and pickling plants.

5. Requirement of suitable preliminary treatment facilities in industries to prevent interference with sewage treatment plant operation.

6. Provision for stern penalties for malicious damage by vandals.

A combination grit and oil trap recommended by the South Dakota Board of Health[6] for use on sewers from garages, filling stations and automobile wash racks is shown in Fig. 7. The oil problem is successfully met at Baltimore[9] by requiring by ordinance that such waste be stored on the premises until collected periodically for disposal under direct control of municipal authorities. The provision of a convenient means of disposal of the oil eliminates need for policing garages and similar establishments.

After a bad fire caused by waste oil and gasoline dumped to sewers at Aurora, Ill., Superintendent W. A. Sperry acted to prevent a recurrence by means of newspaper publicity and direct contact with industrial sources of volatile wastes. The

latter was acomplished by a plant-to-plant canvass of 245 industrial and commercial establishments, during which a verbal notice was given a responsible representative of each concern, a poster epitomizing the sewer ordinance was left and a signed acknowledgement of each visit was obtained. The survey cost $100 and appears to be good insurance against future damage, although it must probably be repeated after several years.

Sewer Ventilation

Ventilation in sewers is necessary to dilute and purge the system of gases which are inflammable, explosive, asphyxiant and toxic. In warm climates where hydrogen sulfide is often a problem, ventilation is also beneficial in controlling disintegration of concrete sewers and structures because (a) the concentration of H_2S in the atmosphere and (b) collection of moisture on exposed surfaces, are reduced.

The degree of effective ventilation in a sewer is usually dependent upon the amount of vent openings and the movement of air across the openings. Thus, it appears that natural ventilation is at a minimum on still days.

Forced ventilation has been found justified in large outfall sewers at Los Angeles[8] and several ventilation stations are in development. Ordinary ventilation practice is probably represented by the procedure at Lower Merion Twp., Pa.[10] "Ventilating covers" having eight 1-in. openings are placed at the upper ends of all lines and approximately at each third manhole, with consideration being given to surface water drainage and proximity to points at which odor might be troublesome, when selecting locations. Buckets are hung beneath ventilating covers to catch debris which might pass through the openings.

To guard against fires and explosions and to eliminate conditions dangerous to sewer maintenance personnel, the city of Los Angeles[8] has a gas survey crew which systematically checks the entire system, making observations at about 60,000 manholes per year. Results of various gas detector tests are recorded and used as basis for correction of dangerous conditions. When the presence of illuminating gas is suspected, the utility company is immediately notified so that any gas main leak may be repaired.

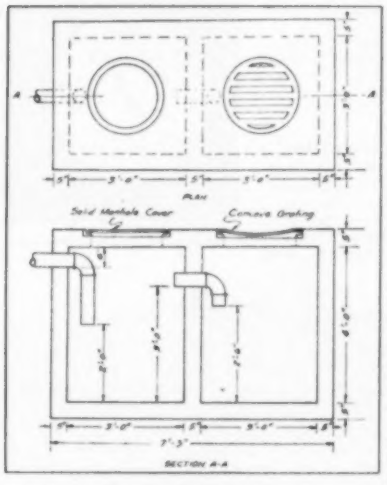

Fig. 7—Combined oil trap and grit basin for garages. South Dakota State Board of Health.

Fig. 5—Two men turn rod into sewer using Flexible Power Drive.

Fig. 6—A recent innovation—Flexible's "SewerRoder" in operation.

Design and Construction Items Facilitating Maintenance

Good design and careful construction of a sewer system will reduce maintenance to a minimum and expedite such work as is necessary. There has been sufficient experience at this time to substantiate present methods of ascertaining sewer sizes and grades, yet there is often a tendency to violate the limitations of good practice, particularly with respect to grades. Every effort to avoid capital and operating costs of pumping stations is certainly justified, but consideration must also be given the less satisfactory service and everlasting maintenance expense which accompany the installation of sewers on flat grades. Where moderate reductions in slope are logical, provision of adequate suitable flushing facilities constitute good practice.

The prevalence of difficulties from roots and ground water infiltration is ample proof that too much care cannot be taken in specifying and installing permanently tight joints. This fact, of course, is generally appreciated and modern jointing methods and materials are already demonstrating their superiority. Careful specification and performance of back-filling is also important in preventing crushing of pipe and movement which results in opening of joints. The use of especially suited pipe and construction methods in sections where foundation conditions are bad or where excessive ground water is present, has been proven to be good economy, even though more expensive in first cost.

Other design and construction details suggested by maintenance personnel as being of importance to their functions are the following:

1. Design of junction chambers so that back-water areas of low velocity, causing deposition of grit, are avoided.
2. Design of storm water overflows so that they are not accessible by vandals.
3. Catch basins of ample size at storm water inlets draining unpaved streets.
4. Complete consideration of local conditions when selecting the type of pipe used for sanitary and industrial sewers.
5. Spacing of manholes not more than 350 feet apart.
6. Lateral sanitary sewers of not less than 8 inches diameter.
7. Smooth flow without splashing or turbulence at manholes or appurtenant structures. (Important where hydrogen sulfide might be a problem.)
8. Diversion and regulator devices of simple design and capable of convenient adjustment.

References

1. C. George Anderson, "Sewer Maintenance," Waterworks and Sewerage, January, 1940.
2. George A. Finck, "Maintaining a Sewerage System," Waterworks and Sewerage, May, 1939.
3. Edward P. Decher, "Sewer Service and Maintenance," Waterworks and Sewerage, September, 1939.
4. J. W. McAmis, "Killing Roots in Sewers with Copper Sulfate," Waterworks and Sewerage, May, 1939.
5. Joseph H. Le Chard, "How a Flat City Cleans Sewers," Public Works, July, 1938.
6. John D. Watson, "Sewer Flushing," Waterworks and Sewerage, August, 1937.
7. A. M. Rawn, "Some Sewerage Operating Kinks," Waterworks and Sewerage, May, 1936.
8. The Clarifier, South Dakota Board of Health, May, 1941.
9. R. E. Brown, "Methods and Problems of Sewer Maintenance," Sewage Works Jour., 12, 969 (1940).
10. Grant M. Olewiler, "Sewer Maintenance," Sewage Works Jour., 9, 809 (1937).
11. Fred D. Bowlus, "Sewer Maintenance," Sewage Works Jour., 12, 977 (1940).

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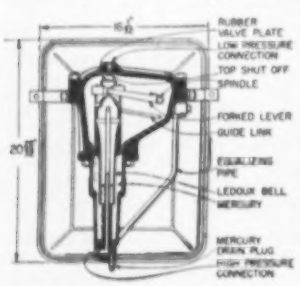
Static Pressure Method—(for location below liquid level). Two types are available; mercury U-tube and float for minimum range of 0 to 50 inches of water, and maximum of 0 to 150 feet of water, and a helical coil for minimum range of 0 to 120 feet of water and maximum of 0 to 600 feet of water.

Bubbler System—For measuring level or specific gravity of corrosive liquids and of liquids with solids in suspension. **For information on Bailey Level Recorders ask for Bulletin 17-C**

• • • **FOR AIR FLOW—Bailey Air Meters** measure Air Flow in main lines and in individual lines to aeration tanks. The register used is similar in appearance to the Ledoux bell type (left) and the flow mechanism is designed to operate on a maximum differential pressure of eight inches of water. **Ask for Bulletin 301 B**

Air Flow from a rotary positive type blower can be measured accurately with a Bailey Electronic Type Recorder. Blower Shaft speed, measured by a tachometer is recorded in terms of Air Flow.

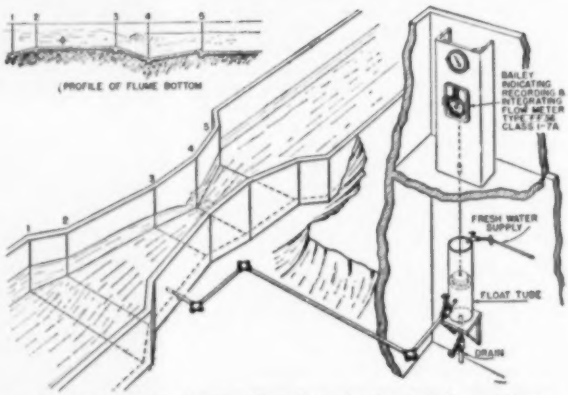


Ledoux Bell Flow Mechanism

BAILEY CONTROLLERS

Bailey Controllers utilize standard Bailey Instruments as the measurement source for automatic control of factors such as flow, ratio, pressure and liquid level. They operate by compressed air and are styled to match other Bailey Gages and Registers.

Bailey Control is fully automatic, dependable and exceptionally flexible.
Explained in Bulletin 17-C


PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF-3K CLASS I-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

Typical installation of Bailey Flow Meter for Parshall Venturi Flume

Bailey Recorder—Controller

pH RECORDER

The Bailey Electronic pH Recorder accurately measures and, if desired, controls hydrogen ion concentration in a solution. The indicating and recording instrument is similar in appearance to a Standard Bailey Register.
Described in Bulletin 234

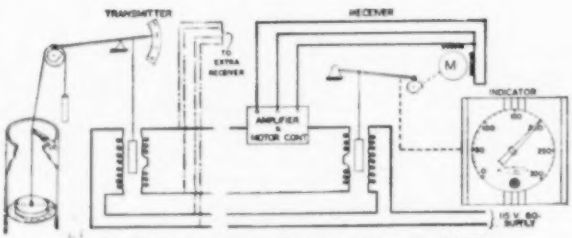
BAILEY TELEMETER

The Bailey Voltage Balance Electronic Telemeter is a quick, accurate means of transmitting position over distances. The measure of any factor which can be made to move the core of a small solenoid transformer may be indicated or recorded at a distant receiver. Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized.

Bailey Large Dial Indicator

LARGE DIAL INDICATOR

Indicators containing the telemeter circuit receiving mechanism may be single or double face and may have 18, 24, or 30-inch dials. Numerals and indicating pointer are large for easy reading. **Ask for Pulletin 17-C**



Bailey Voltage Balance Electronic Telemeter Circuit

PREVENTIVE MAINTENANCE

Checklist for Pumping Units, Electrical Units, Mechanical Units and Personnel

By JOHN D. McDONALD
Supt., Sewage Treatment Plants, Springfield, Mass.

FROM time to time, at meetings, we are told that our pumping stations and plants for the treatment of water, sewage, and industrial wastes have become so mechanically complicated that the average "nongenius" operator is having his hands full keeping things running on an even keel. There are two sides to this problem, and perhaps the designing engineers have been more farsighted than we operators in foreseeing serious manpower shortages. I for one am thankful for a majority of the mansaving equipment and so-called automatic gadgets in our various installations. Of course, such devices must have attention to keep running; but, if given just the minimum of consideration and care, they become pretty faithful servants—and when properly lubricated seldom give much backtalk.

The City of Springfield, Mass. has two primary sewage treatment plants, one of 30 mgd capacity and one of 3 mgd. See Figs. 1 and 2. All sewage is pumped to the 30 mgd plant. It passes under the Connecticut River to the plant site from an attended pumping station in the city, and is pumped by three 15 mgd capacity vertical centrifugal pumps driven by diesel engines thru right angle drives. In addition to this main pumping station, there are seven low lift sewage pumping stations, electrically operated and unattended, varying in capacities from 1.5 mgd to 8.0 mgd. See Figs. 3, 4, 5 and 6. Due to the topography of the city, some of the sewage is pumped three times.

In this system there is about one example of everything in the line of mechanization. There are over 400 electric motors ranging from fractional HP units, operating laboratory equipment, to 200 HP storm water pumps; eight 250 HP and two 425 HP gasoline engines; three 125 HP diesel engines; and 250 assorted pumps ranging from chemical solution pumps to 52,000 gpm sewage pumps. At the treatment plants there is the usual assortment of units including mechanically cleaned racks, detritors, narrow gage railroad for grit disposal, comminutors, clarifiers, sludge pumps, and equipment required for digesters, gas collection and utilization, vacuum filtration and incineration.

Fig. 2—SPRINGFIELD'S 3 mgd Sewage Treatment Plant (The Indian Orchard Plant)

The same organization maintains six gasoline powered flood control pumping stations having a combined capacity of 360 mgd. While these stations operate only about 2.5 per cent of the time, they must be kept in instant readiness and, therefore, are test run for two hours each week.

In the twelve years that this system has been in operation, many valuable lessons in maintenance have been learned and it is hoped that others may profit from our experiences. It is far better, and cheaper too, that equipment be kept running thru a program of preventive maintenance—rather than to have a long, costly and embarrassing shut-down. This is becoming increasingly true each day, what with material shortages, difficult procurement procedures, arbitrary budget cuts, a marked lack of initiative on the part of employees, and the difficulty of luring competent new personnel to the generally low wage civil service positions. All these obstacles make good maintenance a must for those of us responsible for keeping the wheels revolving.

The Program Required

A good preventive maintenance program pays off in several ways, because it will:

Prolong the usable life of the installation
Insure continuity of operation
Reduce unit costs
Establish good public relations
Maintain higher morale among personnel

Basically the program consists only of common sense and good housekeeping.

In general we have found that practically all breakdowns in sewage treatment work fall into one of the following categories:

1. Pumping failures
2. Electrical failures
3. Mechanical failures
4. Personnel failures

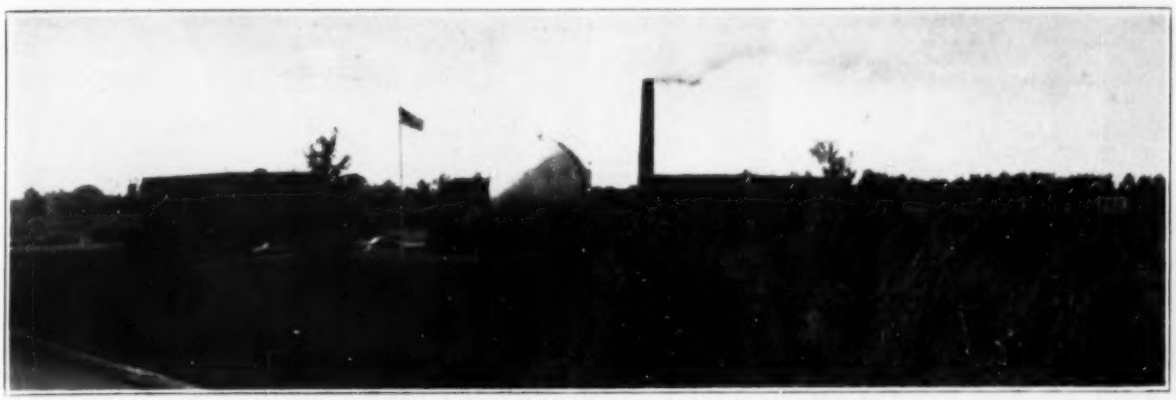


Fig. 1—SPRINGFIELD'S 30 mgd Main Sewage Treatment Plant

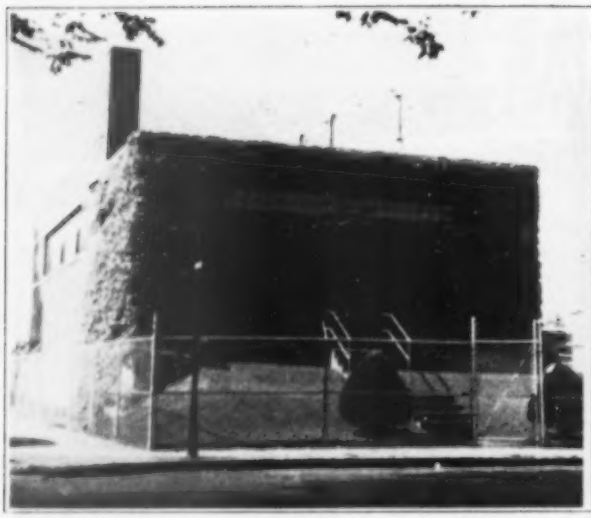


Fig. 3—YORK STREET Pumping Station
The main pumping station delivering sewage under Connecticut River to treatment plant. Station also serves for flood control.

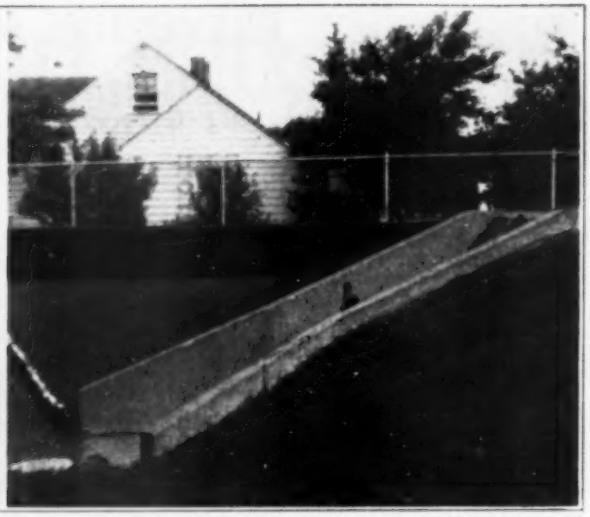


Fig. 4—CAREW STREET Pumping Station
Located in residential area, this station has no superstructure. It is well landscaped and grounds have appearance of small park.

Checklist for Pumping Units

The following program of preventive maintenance provides a useful checklist to reduce failures of pumping units.

Daily Inspection

Note any irregularities of operation
Investigate any change in sound or unusual sound
Check bearing temperatures
Check for proper stuffing box leakage
Check pressure and flow gauges

Semi-annual Inspection

Inspect packing
Check alignment of pump and driver
Drain and refill oil lubricated bearings
Check grease lubricated bearings

Annual Inspection

Remove bearings, clean and examine, and clean bearing housing
Remove packing and examine shaft and shaft sleeves
Disconnect coupling and check alignment
Check end play and correct if factory specifications are exceeded
Clean drain and flush sealing water piping

Note on Packings

When removing and replacing packing rings, be sure to remove and replace all rings and stagger the rings. If there is a lantern ring, be sure it is in line with the sealing water connection and do not change this position when packing in succeeding rings.

Positive Displacement or Plunger Type Pumps

Use good quality square packing
Do not screw glands too tight and keep tension even (This is true in centrifugal pumps)
Should be small amount of leakage. (Also true in centrifugal pumps)
Ball valve chambers should be opened occasionally
In closing see that washer is seated properly
Keep extra valve chamber gaskets on hand
Replace balls before they wear small enough to clog

CENTRIFUGAL TYPE PUMPS

Centrifugal pumps are more commonly used in sewage work. The following check list can be referred to when troubles occur and may help to localize the difficulty and speed up corrective action.

Pump Does Not Deliver

Possible Cause:

Pump not primed
Suction lift too high
Excessive air or gas in liquid
Wrong rotation (Don't laugh)
Suction inlet not submerged
Speed too low
Total system head greater than design head of pump
Clogged impellor

Insufficient Delivery

Possible Cause:

Suction lift too high
Air or gas in liquid
Air leaks in suction line or pump
Foot valve too small or clogged
Inlet valve not completely submerged
Speed too low
Total system head greater than design
Impellor clogged or damaged
Wearing rings worn excessively

Fig. 5—ENGINE ROOM at York Street Station
Diesel engines and right angle drives operate pumps on floor below

Priming Lost After Starting

Possible Cause:

Suction lift too high
Excessive air or gas in liquid
Air leaks in suction line or pump
Suction inlet not submerged

Excessive Power Required

Possible Cause:

Speed too high
System head not in design range
Liquid viscosity differs from design
Foreign matter in impellor or pump
Mis-alignment
Bent shaft
Rotating part rubbing stationary part
Wearing rings worn
Improper packing installation
Gland too tight

Stuffing Box Leaks Excessively

Possible Cause:

Mis-alignment
Bent shaft
Worn shaft or shaft sleeves
Improperly packed
Rotor out of balance

Packing Has Short Life

Possible Cause:

Water seal line plugged
Seal cage (lantern ring) improperly located
Mis-alignment
Bent shaft
Worn bearings
Worn shaft or shaft sleeves
Improperly packed
Gland too tight
Grit in sealing liquid

Pump Vibrates

Possible Cause:

Suction lift too high
Suction inlet not submerged
Operation at too low a capacity
Foreign matter in impellor
Mis-alignment
Foundation not rigid
Bent shaft
Rotating part rubbing stationary part
Worm bearings
Impellor damaged

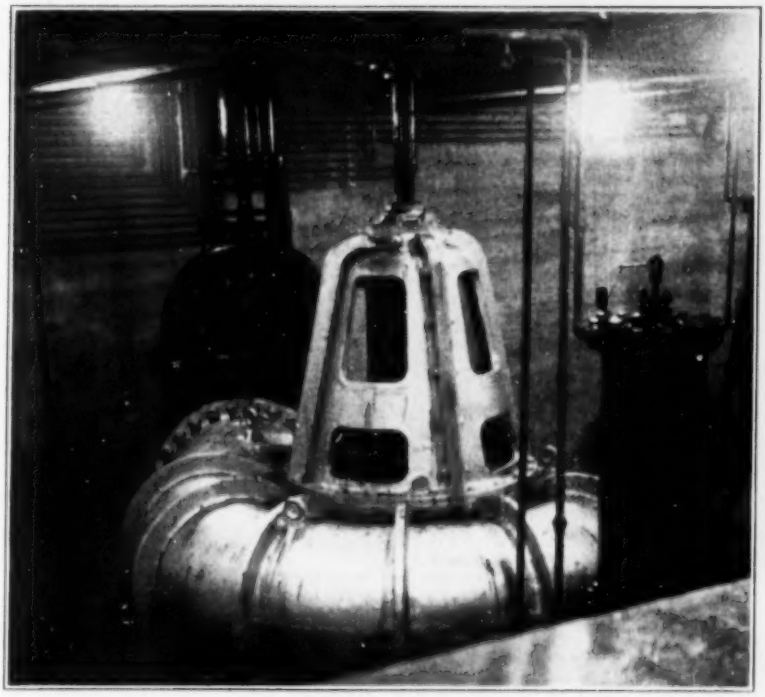


Fig. 6—PUMP ROOM at York Street Station
One 15 mgd pump is shown. Vertical drive shaft is from floor above

Excessive thrust due to internal mechanical failure
Lack of lubrication or improper lubrication

Bearings Have Short Life

Possible Cause:

Mis-alignment
Bent shaft
Rotating part rubbing stationary part
Bearings worn
Rotor out of balance (Vibration)
Improper lubrication

Pump Overheats and Seizes

Possible Cause:

Pump not primed
Operation at too low a capacity
Parallel pump operation not suitable
Mis-alignment
Rotating part hitting stationary part
Worn bearings
Improper packing
Gland too tight
Improper lubrication

Fig. 7—CLAMP-ON Volt-Ammeter
In operation to record current being used by this motor

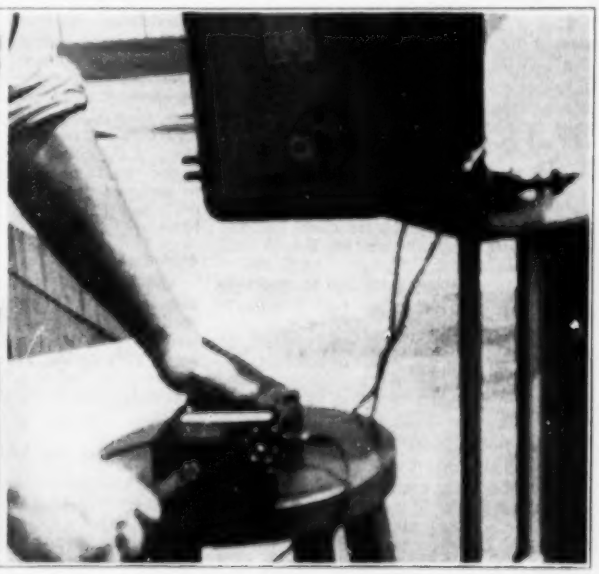


Fig. 8—MEGGER in use
Testing insulation valve of wiring on exposed drive motor

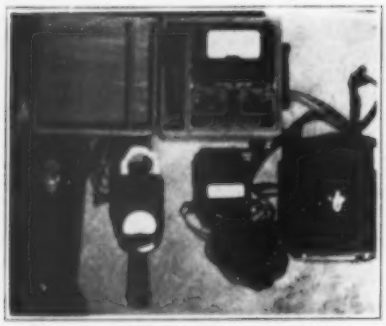


Fig. 9—ELECTRICAL Testing Instruments
Top, industrial analyzer; Lower left, clamp-on volt ammeter; Lower right, megger; and carrying cases

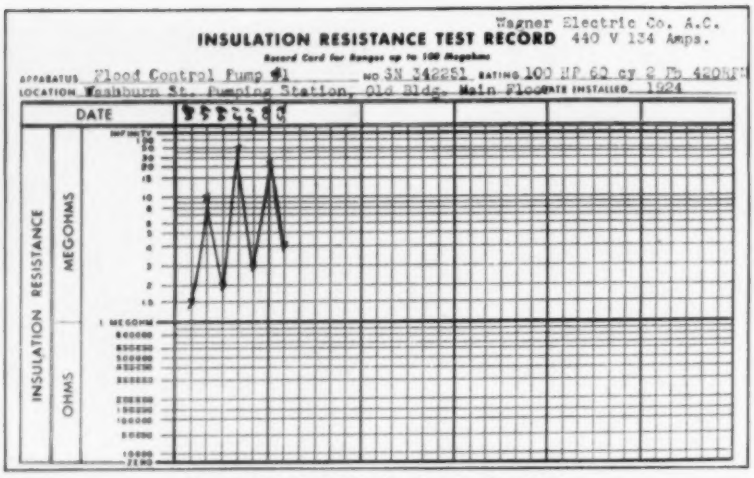

Wagner Electric Co. A.C.
INSULATION RESISTANCE TEST RECORD 440 V 134 Amps.
Record Card for Ranges up to 100 Megohms
APPARATUS Flood Control Pump #1
LOCATION Washburn St. Pumping Station, Old Bldg. Main Floor
DATE
INSULATION RESISTANCE
MEGOHMS
OHMS

Fig. 10—FILE CARD for Megger Readings
Similar file card record is kept for all motors and electrical circuits

Checklist for Electrical Units

We have found that electrical failures generally fall into one of the following categories:

1. Moisture or other foreign matter in motor or wiring
2. Overload
3. Improper lubrication of motor
4. Defects in controls or starting devices

Electrical maintenance can be summed up in one short sentence—KEEP THE APPARATUS CLEAN AND DRY. This is what is meant by good housekeeping and common sense. As simple as it is, look around your own plant and if you are like the rest of us you will find some motor which is getting a raw deal.

Useful Suggestions

Suitable precautions must be taken to protect the equipment from moisture, oil, dust, grease and corrosive gasses.

Watch overhead dripping and excessive splashing when washing floors.

In damp and humid locations install a humidity control switch to operate a circulating fan to correct the condition.

Low voltage heating can be used in locations where normal usage does not keep windings dry.

Tools, oil cans, bolts, etc., must not lie around the motor or frame.

Keep motors free of dust by the occasional use of compressed air or a hand bellows. When using compressed air, the pressure must be reduced to a low pressure which will not damage the insulation and it must be dry.

There must be periodic check of insulation on equipment in hazardous locations.

Always make a complete check on any idle equipment prior to putting it back into operation.

Use only qualified personnel to maintain electrical equipment.

Have hard and fast rules relative to power being *off* while work is being done on electrical equipment.

Try to follow the manufacturers instructional manual.

Your Own Trouble-Shooter

Now all this may sound very complicated and would seem to require the services of an electrical engineer to make these checks but this is not so. Any one of your good operators can become your electrical trouble shooter and call your attention to a spot where corrective action may prevent future trouble.

The Volt-Ammeter

The equipment needed is not too expensive. For a start there should be a clamp-on volt-ammeter. The photo, Fig. 7, shows the simplicity of its use. Instantly the load on any motor can be measured. Which brings up another point, after reading the name-plate data on the motor, when the plant is first put into operation a check on each starting device should be made to see that it is properly fused or protected with the right overload safety heater. In addition to ascertaining the possible overload, this information is valuable in running down causes of low power factor due to underloading of motors.

The "Megger"

Another valuable piece of equipment is the "megger," shown in Fig. 8. Its use is very simple. With this small portable device, the insulation resistance of any equipment or circuit can be measured instantly and a potential breakdown discovered. The instrument is invaluable in locating open circuits and other electrical failures.

At this installation all motors are card indexed and periodically meggered, the time interval being determined by the location and use of the motor. Motors in damp environments and not constantly in use must be checked more frequently. These readings, entered on a card and plotted on the logarithmic graph, give an instant visual story of the condition of the windings; and if the resistance is low will warn you not to energize this motor prior to drying out the insulation. One of our record cards is illustrated in Fig. 10.

Other Equipment

The industrial analyzer is another valuable asset to your plant, although not really a necessity except in the larger installations. For our set-up, I consider it necessary. This device is illustrated in Fig. 9.

The final tool at your electrical serviceman's disposal is the simple pocket voltage tester.

Checklist for Mechanical Units

Our experience shows mechanical failures generally to stem from one of the following factors:

1. Normal wear and tear
2. Points of excessive abrasion
3. Improper lubrication
4. Corrosion

We must be resigned to the fact that normal wear will take place as the price of operation. We only can check regularly and correct conditions before excessive wear causes a failure at an embarrassing time. To prevent this, we should schedule periodic replacement of wearing parts and do the work as near as possible under ideal conditions.

In places where excessive wear from abrasion or other peculiarities of operation can be anticipated, hard facing can be welded on surfaces at these points by the use of a relatively inexpensive welding machine. One of the more interested operators at your plant can be trained in this work. It makes the ideal type of work to do during the night shifts or on week-ends when both equipment use and supervision are at a minimum. Examples of this work are illustrated in Fig. 12.

Advice on Lubrication

To minimize failures from improper lubrication, the best recommendation is to conform as closely as possible to the procedure given in manufacturers' instruction manuals. After all, the maker of the equipment should know more than anyone else about how to keep it running. Go along with the maker's instructions until they are proved wrong.

A Routine Program

Next, organize a definite lubrication program. All the major petroleum companies have expert lubrication engineers who will gladly survey your installation at no charge and submit an excellent program in which the total number of lubricants will be minimized for simplicity. This, done in conjunction with the manufacturer's recommendation, is advisable to reduce the required number of lubricants around your plant. In this way you can continue to deal with your favored petroleum outfit. After the program has been organized, fix the responsibility for carrying it out. We have found that it is better for one man to do all this type of work. Then he has no reason to assume that "George" will do it, and neither will five men grease the same motor just because it happens to be used on all shifts.

Bearing Failures

Under lubrication, bearing failures are especially important and should be discussed

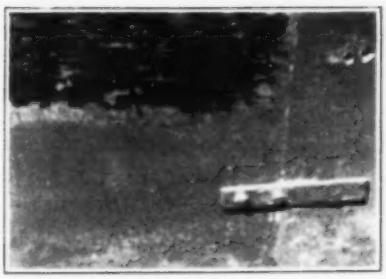


Fig. 11—CORROSION Prevention This exposed steel plate is being scraped and will receive a coat of rust inhibiting paint

briefly. The most common causes of bearing failures are:

1. Carelessness—This means allowing dirt or foreign matter to collect in the housing
2. Overloading
3. Improper lubricant
4. Over lubrication
5. Lack of lubrication

In regard to the last two types of failures, I would pick overlubrication as the greater evil, particularly in reference to motors and bearings. At least if it is lack of lubrication, the sound will soon call your attention to the lack but for over lubrication, your first knowledge may be a burned out motor due to the breakdown of the insulation on the windings because they may be impregnated with surplus oil or grease. In short, bearing lubrication may be summed up in a nutshell—SUFFICIENT GREASE FOR LUBRICATION WITH A PLACE FOR THE EXCESS TO GO.

Corrosion Failures

Corrosion failures generally are due to attack caused by moisture or by chemicals. Exposed metal surfaces must constantly be protected against corrosion. Each person has a right to his own favorite protective coatings—but be sure you do have one and that you use it freely. It should be applied frequently to all exposed metal surfaces: replacement steel for rails and gratings is scarce, and costs money. See Fig. 11.

To protect against chemical corrosion, suitably resistant materials must be selected for each condition. For example, all equipment in contact with ferric chloride should be rubber covered or rubber lined. Corrosive atmospheres should be well ventilated.

The application of protective paints and coatings is another type of job particularly suited to night shift operators, as the amount of work done is clearly evident.

Proper V-Belt Installation

Among preventive measures against mechanical failures, there should be some mention of V-Belts. Listed below are some of the conditions to be avoided in order to maintain proper installations. Check each of these:

Overtension
Undertension
Unequal lengths in multiple installations
Belts left idle too long
Overage belts
Foreign matter on belts
Corrosive atmosphere
Sheaves mis-aligned or worn
Overload at start
Vibration

Checklist for Personnel

A proper training program is of first importance to reduce the frequency of personnel failures—and such a program can be very simple. It means, first, that new employees must be made to feel they are a part of the organization; second, that they really are necessary in the overall municipal function; and, finally, how their job is to be done.

Clear Instructions

To aid employees in doing their jobs properly, the following items are most important:

1. Instructions must be definite. You or your supervisor must know what you want done and also a way to do it. This information must be clearly transmitted to the employee. Being vague generally means that you don't know exactly what you want done yourself and subconsciously the employee gets to feel the same way.
2. The responsibility for carrying out orders must be fixed. The employee must understand that he and he alone is the one to do a particular job.
3. There must be instilled in the employee a confidence in his superiors. This is axiomatic and ties in with the above.

Personal Responsibility

With personnel, it has been our experience that the average employee is happier when assuming some responsibility. He, too, derives a certain satisfaction in repairing or prolonging the life of equipment and should be encouraged to do so. Make the manufacturers instruction manuals and booklets available to the employee—*do not* keep them under lock and key in your office.

If possible, subscribe to a number of engineering magazines and set up a library available to the men, perhaps where they have their lunch. Our men have come to us with several fine maintenance ideas which were picked up in this manner.

Do not assume an attitude that to understand the equipment is above their mental plane but, to the contrary, encourage their thinking and ask for and be receptive to ideas and suggestions. They may not always be acceptable, but you must listen and explain away the poor one by logic and not by ridicule.

Tools are Essential

Now to get these minor adjustments and repairs done daily and by all employees, there must be a minimum assortment of tools and equipment available. The more valuable and less frequently used tools may be kept in security, but the commonly used tools must be made available so that their lack cannot be used as an excuse for failure to perform some maintenance function.

Maybe a few small tools will be missing occasionally but the average plant of this type cannot stand the expense of a tool room and tool issue man. All the missing tools in a year wouldn't pay one week's cost of such a set-up. And if too much stuff is missing, you have a personnel problem not a tool problem.

We have found it to our advantage to equip each of our shift operators with a small tool box with a minimum assortment for which he is more or less responsible; in fact, it has worked out so well that many of these men have supplemented these tools by purchases of their own for special items.

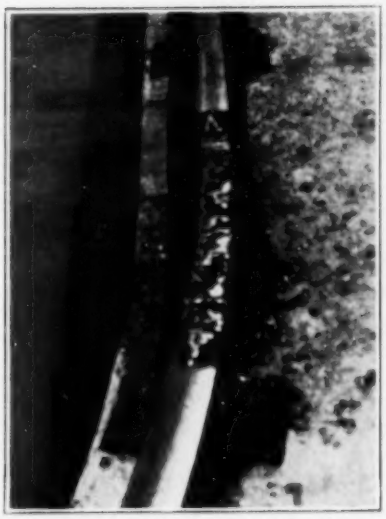


Fig. 12—EXCESSIVE Abrasion Detritor track being hard faced at point of curvature. Work looks crude but adds many years to life of rail

The basic tools and equipment for a plant of our size includes:

Wood tools

Hand saws, plane, squares, brace and collection of bits, chisels, screw drivers, level, axes, claw hammer, sledge, rules, steel tape.

Iron tools

Vise with solid bench, portable electric drill with large assortment and extra drill bits, motor driven two wheel grinder, hammer, good selection of wrenches, sockets, open end and adjustable, combination pliers, electrician pliers, tin snips, and a one ton hoist.

Pipe tools

Set of stocks and dies, pipe cutter, reamer, pipe wrenches, pipe vise, packing and caulking tools, and an assortment of common size nipples, ells, unions and tees.

Miscellaneous tools

Emery wheel, oil stone, assortment of nails and screws, wrecking bar, crow bar, soldering outfit, blow torch, electric soldering iron, lawn tools, hoses, picks, shovels, wheelbarrows and a proper place to keep and store these tools.

It would help all operators if the designing engineers made these tools and equipment a part of the original contract to be supplied with the plant. That is the logical time to get the funds through for this type of purchase. The city fathers are always reluctant to make appropriations for equipment for their new plant.

The Preventive Maintenance Program

To return to the opening statement relative to mechanization. It must be admitted that mechanization can be a nightmare if there is a succession of serious failures. But the specter of manpower shortages can also be a nightmare. I think the modern designers and alert equipment manufacturers are on the right track in trying to mechanize as far as possible but only with tried and proven devices. It then becomes our problem to keep these machines in motion. In this article, an attempt has been made to point out ways to forestall unscheduled interruptions in operation.

SEWAGE TREATMENT PLANT EQUIPMENT

By FRANK L. FLOOD

Partner, Metcalf & Eddy, Cons. Engrs., Boston, Mass.

1—Racks, Comminutors, Grinders, Triturators

SOME years ago Dr. Karl Imhoff made a rather extensive tour of United States and Canada inspecting sewage treatment plants. Near the end of this trip he observed to the late Mr. Harrison P. Eddy, that "in America it is fashionable to be mechanical." The trend, as observed by Dr. Imhoff, has continued and developed so that today it is not only fashionable, but practically necessary "to be mechanical" in order to take advantage of advances and developments in sewage treatment methods and processes.

Mechanization of Sewage Treatment

The mechanization of sewage treatment has not been, and is not free of problems which trouble designers, manufacturers, and operators. Initial installations of new processes and equipment are usually accompanied by difficulties necessitating changes, adjustments, and further developments. Even in the case of equipment which has been used for many years, it is desirable occasionally to evaluate experiences and to consider what lessons have been learned and what improvements can be made. It is recognized that the individual experiences may not be general. The characteristics of sewage and of the materials removed therefrom, vary so widely from time to time and from place to place that individual experience with any particular piece of equipment may range from highly satisfactory to unworkable. There is an old saying that "what is one man's food is another man's poison," and another that "the proof of the pudding is in the eating."

However, from the extensive experience with many treatment plants, some general conclusions can be derived which should be helpful to sanitary engineers in their search for the best equipment for any particular service.

The designing engineer's problem is to specify and procure equipment that will perform the desired services in a satisfactory manner for a reasonable life and involve a minimum of maintenance and operating expense. The manufacturers, without doubt, have similar aims, but they are in general in a highly competitive field, and unless the plans and specifications are clear and specific, the client may not always obtain the best equipment for the particular service. Much equipment in the sewage works field is subjected to abrasive and corrosive conditions. Equipment must be sturdy and careful attention given to choice of materials or to painting and protective coatings. Ready replacement of parts subjected to wear should be provided for. Equipment which does not satisfactorily perform the service for which it was provided causes headaches to the operators and reflects unfavorably upon the designing engineers and the manufacturers.

Sewage plant mechanization places certain responsibilities on the authority served. The necessary personnel and funds for maintenance, operation, renewals and repairs must be provided. The personnel must be capable and willing to make the equipment function in accordance with its purpose. A great deal of expensive equipment at sewage treatment plants may be seen lying idle, serving no useful purpose and deteriorating from lack of the necessary funds or the will or the know-how to make it work. Some of this idle equipment was possibly not suitable in the first place, but much of it could be operating successfully with proper care.

Racks

The operation of mechanically cleaned racks has frequently been accompanied by excessive wear on moving parts, stalling of the rakes, failure of float-operating controls to function, excessive corrosion of rakes and bars and other difficulties with resultant excessive repair and maintenance costs. Improvements and refinements in design make it possible to eliminate some of these troubles.

The difficulties encountered in the operation of large mechanically cleaned racks within the Chicago Sanitary District, have been given considerable study and analysis. The fundamental principle of design which greatly reduces the cost of maintenance and repairs as reported by L. M. Johnson[1] may be summarized as follows:

1. All parts should be designed to carry any loads required of them.
2. Motors should be selected within the maximum safe stresses of all parts.
3. Removable mild steel wearing strips should be provided on chain guides.
4. The rack mechanism should be pivoted at the floor line so that it can be lifted out of the flow in the event of a jammed rake.
5. The chains should be of heat-treated malleable iron.
6. The sprocket teeth should be chilled to produce extremely hard wearing surfaces.
7. Wide wearing shoes should be provided on the chain side bars.
8. The rake teeth should be of high bending strength and readily replaceable.
9. The rakes should be operated intermittently by time switches.

The city of New York accepted a design of mechanical rack-cleaning equipment for the Manhattan grit chambers in which the teeth entered the screen bars against the

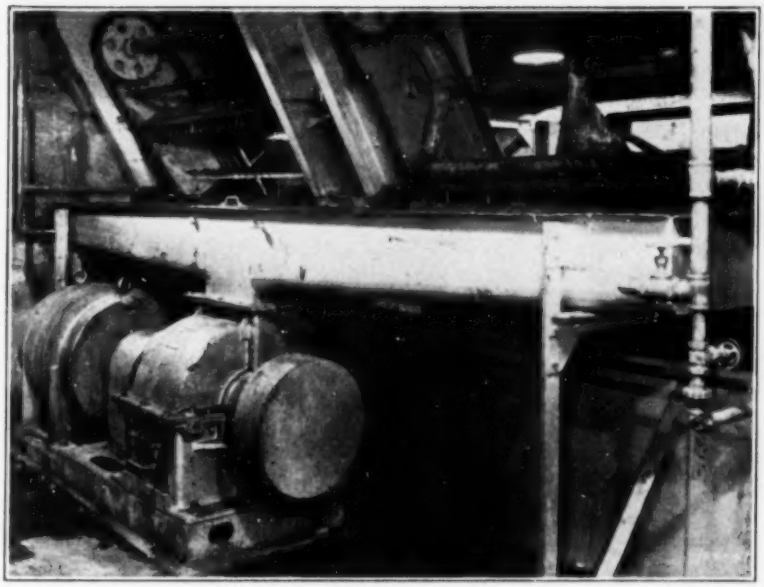
(1) Municipal Sanitation, August 1938, page 391.

Bristol, Conn.—Bypass Rack and Chicago Pump Co. Comminutors

flow at the bottom. Thence the rake moves in an upward direction with the teeth protruding between the bars out on the face of the rack carrying screenings along the bars and over the top. The rakings fall off as the rakes disengage the screen bars. The results of operation of this installation at the Manhattan grit chambers were so satisfactory that the city of New York has, we believe, settled upon this type of rack for subsequent installations.

After a thorough investigation of the operation of the racks at the Manhattan grit chamber, Mr. Karl R. Kennison, Chief Engineer, Construction Division, Boston Metropolitan District Commission, adopted this type of rack with some modifications for the racks at the Nut Island plant in the Boston South Metropolitan Sewerage District. This type of rack has also been adopted for installation ahead of the main sewage pumps at the Toronto Ashbridges Bay sewage treatment plant.

For a while, it appeared that comminutors possibly would displace mechanically cleaned racks generally as the first step in treatment at sewage treatment plants for all except very small and very large plants. However, it has developed that comminutors may advantageously be preceded by grit chambers in order to reduce the cost of replacement of worn parts. Grit chambers are now almost universally required at sewage treatment plants regardless of whether or not the sewerage system is on the separate or the combined plan. In most instances, such grit chambers, particularly where equipped with mechanical grit-removal mechanisms should be preceded by coarse or medium racks. Thus it would appear that mechanically cleaned racks will still be required for many sizeable sewage treatment plants in the future.



Screenings Grinder—Jeffrey Mfg. Co.

Operation Control

Experience has indicated that the maintenance work required on racks is substantially in proportion to the hours of operation. Consequently controls have been developed to assure that the racks will be operated intermittently as needed.

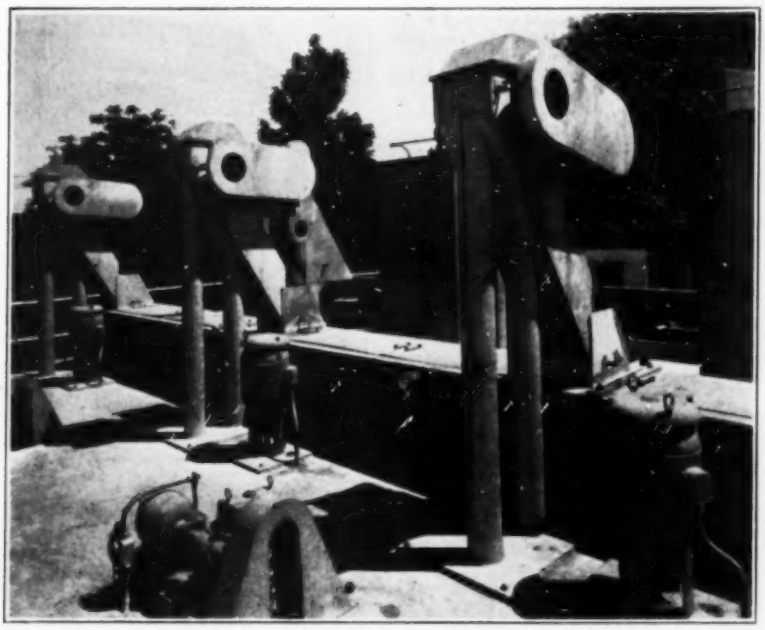
Common methods of control include time clocks and floats operating on either high-water level in part of the rack or the differential water level in front of and following the rack.

The clocks can be set to operate the racks intermittently. To eliminate possible overload on the rack between periods of operation, it is customary to set the operating time interval so as to take care of the maximum rate of accumulation of materials on the rack. Obviously, for much of the time, the rack operates more frequently than is required, resulting in unnecessary wear on the mechanism and on the controls. The clock controls involve less installation cost than float or air controls and are not subjected to the difficulties encountered with float controls.

Some authorities require that all mechanical rack operating units, normally operated by timing devices, be provided with auxiliary float controls which will set the raking mechanism in operation at predetermined high-water marks independently of the timed control.

The use of float controls has been troublesome at some installations because of solids accumulating on the floats and on suspension cords and because of their corrosion in the rack channels. The condition as regards the accumulation of materials on floats has been corrected in part at least, by providing float wells adjacent to the rack channels and connected thereto. A small quantity of flushing water creating a flow from the float wells into the rack channels can be provided to keep the float wells reasonably fresh and free of sewage solids. Corrosion can be overcome for the most part by careful selection of materials of construction.

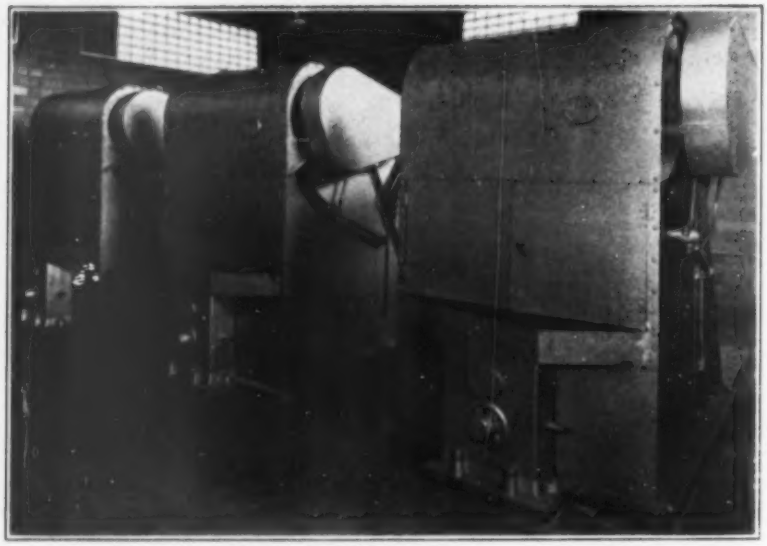
To eliminate the difficulties encountered with float controls, a system of controls which rely on differential air pressure in pipes, immersed in the sewage in front of and behind the rack has been developed. This system is reported to give very satisfactory results. A small amount of air is necessary to activate the controls.



Decatur, Ill.—Screenings and Grit Separators Mechanisms by Walker Process Equipment Co.

Rakings

The materials removed by racks are offensive to sight and smell. It is desirable to dispose of them promptly with a minimum of handling. Much of the material removed by racks can be disposed of with the other sewage solids after grinding or comminution. Pieces of metal and sizeable chunks of wood should be removed from the rakings and disposed of separately. The common methods of preparing the solids returnable to the sewage flow, are by comminutors, grinders, and triturators. At the Los Angeles Hyperion plant, the rakings removed by the racks ahead of the Dorr detritors will be treated by an installation



Denver, Colo.—Automatically Cleaned Bar Screens and Chain Belt Screenings Triturator

of Chicago comminutors. At the Toronto Ashbridges Bay plant, each of 6 racks will be equipped with a Jeffrey grinder. The rakings will be discharged onto a sorting table and manually fed to the grinders after materials not suitable for grinding or return to sewage flow have been removed.

At Baltimore, there are a number of installations at which the rakings at each rack discharge to a short belt conveyor. These rakings are thence carried to a separate grinder for each rack and are comminuted. Keefer reports that these installations work automatically without the necessity for manual removal of metallic and bulky materials. The evidence at several other plants is that it is not safe to rely upon automatic operation for feeding rakings to the grinders.

Comminutors

For purposes of discussion the word comminutor will be used to denote mechanisms which intercept and cut up coarse sewage solids while still immersed in the sewage flow. Until recently the Chicago Pump Co. comminutors have had competition in this field primarily from a combination of mechanically cleaned rack and grinder or triturator. The Worthington comminutor has been introduced recently and other machines for cutting up solids in the sewage flow have been, or are being, developed.

Essex Fells, N.J.—Worthington's Comminutor

While the teeth, comb and drum of the Chicago comminutor have been made of tough, wear-resisting metal, experience has shown that the wear is considerable, particularly on combined systems, unless the comminutors are preceded by grit channels. The Chicago Pump Co. has made recommendations for location of comminutor in respect to grit chambers as follows:

"Where grit chambers are required to remove heavy grit from combined sewage or gravel from street-wash, it is preferable to locate the comminutors downstream from grit chambers.

"Where it is not feasible to locate comminutors downstream from grit chambers due to structural difficulties, or to the possibility of clogging mechanical grit-removal mechanisms by uncut rags, special precaution should be taken to make the comminutor basin as accessible as possible for periodic removal of grit by the operator, to prevent undue accumulations."

Where grit chambers are required but conditions do not make it advisable to install mechanical grit-removal equipment, the comminutors usually can be conveniently located following the grit channels. Where mechanical grit-removal equipment is provided and comminutors are located ahead of the grit channels, then not only must the special precautions noted by the Chicago Pump Co. be followed but it should be recognized by the designer, operator, and owner that the necessary labor and expense must be provided to maintain reasonably sharp teeth to maintain reasonably sharp teeth and to replace worn parts as required.

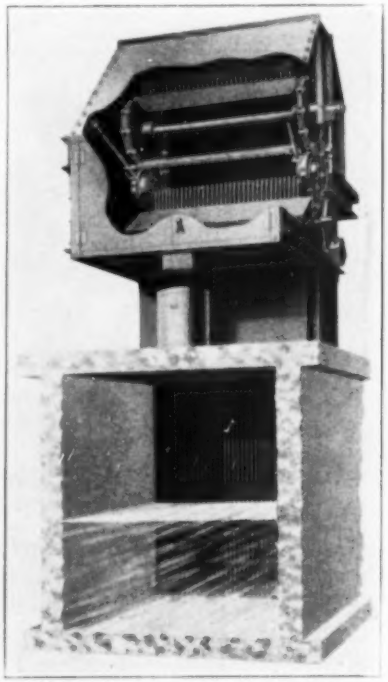
At the Nut Island plant, Boston, it was deemed advisable to install mechanically cleaned coarse bar racks ahead of the mechanically cleaned grit channels and to provide comminutors to handle the normal dry-weather flow at the effluent end of the grit channels. Supplementary mechanically cleaned fine screens were provided at the effluent end of the grit channels to treat storm flows in excess of normal maximum dry-weather rates. The screenings removed by both the coarse and fine racks will be returned to the sewage flow ahead of the comminutors. The comminutors were supplied by the Chicago Pump Co. and the rack equipment by the Jeffrey Manufacturing Co.

Grinders and Triturators

Machines for cutting up sewage solids are removed by racks and screens, out of the sewage flow, are available in two main types, the grinder as manufactured by Jeffrey and by Gruendler and the triturator as manufactured by the Chain Belt Company. The grinder is designed to grind the screenings between a high-speed rotor equipped with swing hammers, and a serrated shredder plate. The swing hammers are commonly made of high-carbon steel hardened and tempered, made easily removable and capable of being shifted end to end and side to side so as to give four wearing edges. The shredder bar assembly is also usually made of high-carbon steel, hardened and tempered, and with easily replaceable bars.

The triturator at one time consisted essentially of a toothed rotor revolving at high speed between two grates, the cutting teeth intermeshing the grate bars. As presently described, the toothed rotor operates against a perforated screen for positive extrusion of the rakings through the screen holes and simultaneous shear cutting by the teeth against the screen.

At Buffalo, N.Y., the screenings from the fine racks were passed through triturators for the first six years of operation at the Birds Island plant. For the past four years, however, the screenings have been disposed of by burial after the operators reached the conclusion that handling, transporting and burial presented less of a problem than grinding. At this plant, it was found that the screenings contained so much hard material, such as bits of stone and pieces of metal and wood, that the effective life of the teeth was very short. New or resharpened teeth became dull in a very few hours of operation and then did not properly shred the material passed through them. This gave a great deal of trouble further along because of the condition in which the rags were left.



Thru-Clean Bar Screen by Link-Belt Co.

Both grinders and triturators have been in successful operation for at least ten years in moderate-sized sewage treatment plants with which we have been associated as engineers.

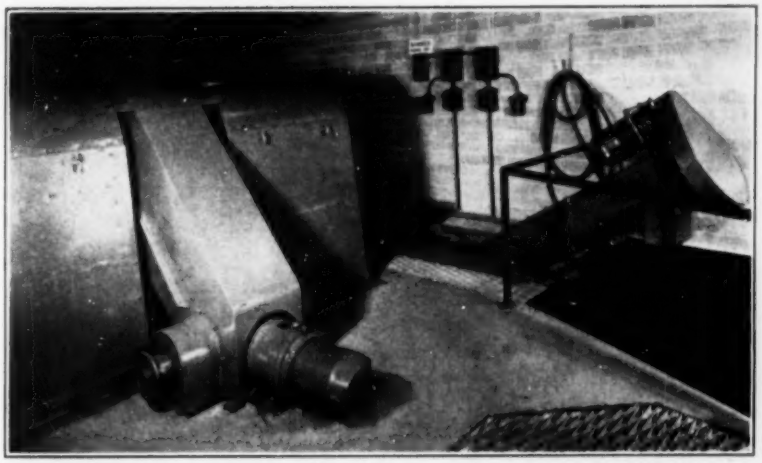
Balls of material have been known to accumulate on the grinder shredder plate which cause trouble later on in the plant as they finally drop off. It is believed advisable, when feasible, to return the discharge from grinders and triturators to the sewage ahead of the racks.

Other Operating Information

As typical examples of operating installations the following paragraphs set forth information on three plants.

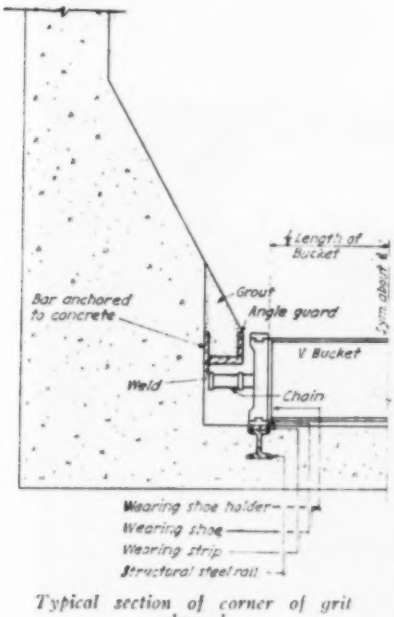
A mechanically cleaned bar rack and grinder as supplied by the Jeffrey Mfg. Co. was installed at the North Adams, Mass., sewage treatment plant during 1936 and has completed 13 years of operation. The maintenance work on the individual parts as reported by Paul Fleming, Plant Supt., has been very small. The rake jams occasionally if the chains become uneven, but this has not been considered serious by the operators. Automatic operation of the grinders is not employed as it has been learned from experience that large masses of rakings will clog the grinder necessitating opening it up and cleaning it out. New rotor weights have been placed on the hammers three times in 13 years. This involves only a moderate expense.

A mechanically cleaned bar rack and triturator as supplied by the Chain Belt Co. and installed at the Tonawanda, N.Y., sewage treatment plant was placed in operation in 1940. The operating experience has been reported to the author by James J. Kampas, Chief Operator, and Benjamin Hinkey, City Engr. The rake is operated either by time clock or manual control. Large objects have at times jammed the rakes at the bottom of the rack necessitating dewatering the rack channel for their removal. It has been found necessary to replace the rakes, bars, lower sprockets, and scraper arms because of wear and tear. The triturator teeth are periodically sharpened and need to be replaced on the average after two to three years of service.



Sheboygan, Wisc.—Two Rex Grit Collectors and Rex Separate Grit Washer

Inquiry has also been made as to the operation of the rack equipment at the Bloomington and Normal Sanitary District. In the January 1940 issue of Water Works and Sewerage the satisfactory operation of the Chain Belt mechanically cleaned bar rack and triturator was described by Orie J. Hendryx, then Supt. of the Bloomington and Normal Sanitary District. Mr. George L. Hall, the present superintendent of this plant, reports to the author that the original equipment is still in use except that the chain was replaced in 1948. Equipment to replace the lower boot section including sprockets and pins is at hand to make this replacement when it becomes necessary. Mr. Hall reports that the operation of the equipment during the past eight years has been satisfactory.



Typical section of corner of grit channel

2—Grit Chambers

The more prominent of the various means that have been used for the mechanical removal of grit from grit chambers at sewage treatment plants may be summarized as follows:

Scraper blades or flight conveyors
Bucket conveyors
Inclined flight conveyors
Inclined screw conveyors
Vertical bucket elevators
Belt conveyors
Grab buckets
Grit eductors and ejectors

The above equipment may be used separately or in various combinations. The grit may be collected at the influent end of channels by means of flight conveyors, scraper blades, or horizontal bucket conveyors, and then elevated by inclined flight conveyors, inclined screw conveyors, or by vertical bucket elevators or be pumped by eductors or ejectors. The grit as elevated from the individual channels may be then transported by means of flights, buckets and screw or belt conveyors to further treatment units or to points of disposal.

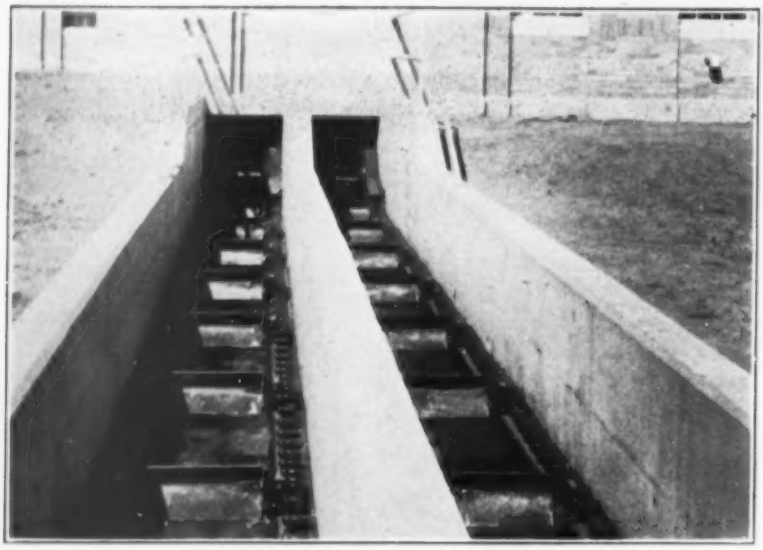
It is difficult to obtain manufacturers' agreement on recommendations for grit channel equipment. Each manufacturer has his own ideas as to what should be provided. These ideas are influenced, in part at least, by one of several reasons. Generally, the manufacturer desires to incorporate methods and equipment which: (1) he has tried and perfected to a reasonable working basis, (2) has become more or less standardized with the company, (3) he holds patents on, (4) will avoid infringement of patents held by others, or (5) will enable the manufacturer to compete on a favorable basis for the work of furnishing the equipment.

Severe Wear Encountered

The scraper blades and flights used for conveyors and elevators, the bucket conveyors and elevators or the inclined screen conveyors and elevators, all require moving equipment immersed or partially immersed in the sewage and grit. Due to the abrasive character of the materials handled and other operating conditions, grit chamber equipment of this type is subjected to a high rate of wear. In its design, therefore, the emphasis should be placed upon rugged, durable construction, with ready means for replacement of worn parts.

The operation of equipment in the grit chambers at Buffalo has been described by Johnson.[1] In these chambers the grit is collected by flights riding on rails embedded in the concrete floor. The shoes on the flights wore out rapidly and when replaced by shoes of highly resistant metal the soft steel guide rails wore down and had to be renewed. A design was developed in which the wear was taken by an easily replaceable wearing rail.

Tail bearing assemblies at the ends of the inclined screen conveyors were cut to pieces within a short time by the passage of fine grit particles into the bearing. The life of this bearing was prolonged by a combination of steel, rubber and paper gaskets with an adjustable packing gland which has excluded for a longer term and to a greater extent the working of abrasive material back into the bearing.



Rock Island, Ill.—Jeffrey Grit Collectors

The grit chamber equipment at the District of Columbia Blue Plains plant was originally supplied with inclined screw conveyors with thrust bearings near the bottom of the grit hoppers. Because of continual submergence in grit, these bearings lasted only a very short time. To overcome this difficulty, the bearings were replaced by ball thrust bearings above the sewage level. In addition to eliminating the frequent failure of the underwater bearings, much smoother operation of these units resulted.

The grit chamber equipment at the Toronto Ashbridges Bay plant includes bucket conveyors and elevators on parallel endless strands of chain. The rails in the concrete channel bottom have readily replaceable wearing plates. The attachments supporting the buckets include removable wearing shoes of gray cast iron to ride on the rails imbedded in the channel bottom and on the angles supporting the return flight. The return angle rails and the removable wearing shoes are of ½ in. thickness.

In an effort to reduce the wear on chains, attachments, shoes and rails, the Chain Belt Co. has devised and advocated construction as shown in the accompanying figure. This provides in effect a chain guard which prevents grit from falling directly onto or compacting directly upon the conveyor chain, thus reducing the abrasive action of the grit on the chain, its supporting attachments, and the guide rail.

Overload and Shear Pins

In the past, grit-collector equipment has been protected from overload largely by the use of shear pins. The objection to the use of shear pins has been that as these break under overload the operators have been inclined to replace them with stronger pins until a chain, sprocket, shaft or other element is seriously damaged or broken requiring major repairs. The development and use of stalling torque motors on grit chamber equipment so as to eliminate the use of shear pins was discouraged during the war and has been somewhat neglected since. Recently adjustable overload release devices have been advanced which are designed to mechanically disengage the grit collectors from the motor when overloads are encountered.

In order to secure truly competitive bids on grit chamber equipment, it may be necessary to provide detailed specifications and reasonably detailed plans.

The hunting tooth or extended life sprocket of alloy cast iron with a nickel content of 1.00 to 1.25 percent and a chromium content of 0.45 to 0.65 percent with teeth chilled to give a hardened wearing surface should give reasonable life.

Velocity Control

In many grit channels the effective removal of grit is dependent upon control of velocity. Various devices have been used to effect control so that a velocity in the vicinity of 1 ft. per second is maintained throughout the range of sewage flow from minimum to maximum for which the channel is designed. This may be accomplished by properly designed proportional weirs for rectangular channels which increase the depth of flow in direct ratio to the increase in rate of flow. This plan may require considerable loss of head at the grit channel during maximum rates of flow.

It is common practice at present to provide control sections following grit channels, such as the Parshall flume or the Camp regulator as manufactured by American Well Works,[2] and to design the cross-section of the grit channel to suit the backwater conditions created by the control section. Where the Parshall flume serves as the flow level control section for the grit channels, it is also usually adapted for measurement of sewage flow.[3] It is convenient to provide a flow indicator at the flume and adjacent to the grit channels so that the experienced operator can readily determine the number of channels which it is advisable to have in operation.

Grit Conveyors

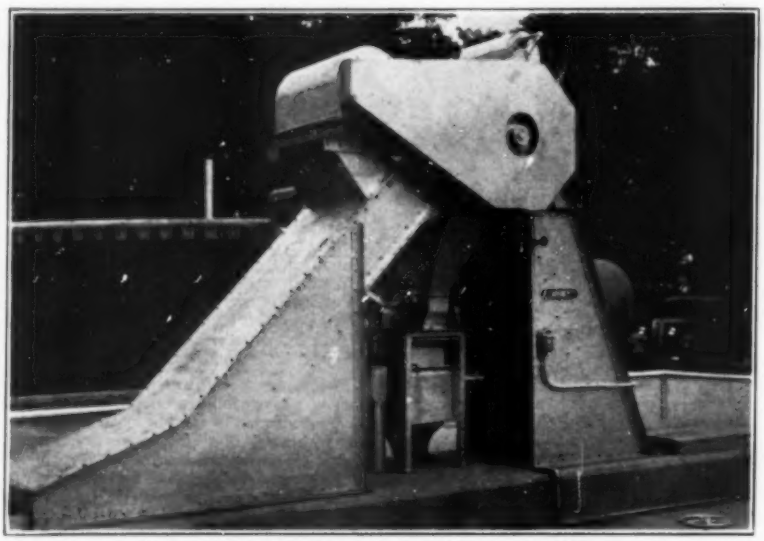
Belt conveyors for horizontal transportation of grit from multiple grit channels to grit-washing, storage, and disposal points, appear to operate with less maintenance costs than scraper, bucket, or spiral conveyors.

Pneumatic grit ejectors as made by Krajewoski-Pesant Manufacturing Co. are provided at the Tallmans Island plant in New York for discharging grit from the grit house to storage tanks in an adjacent building.

Fuller[4] reports successful operation with a pneumatic grit washer and ejector at Olean, New York. He states that formerly six man-days were required to remove the grit by hand, chain hoist, and truck, followed by burial, whereas the air-lift system washes the grit and disposes of it in thirty minutes. The washed grit is discharged to the Allegheny River. It is noteworthy that the air-lifted grit discharges through a 6-in. pipeline as compared with 3-in. and smaller pipelines used in connection with some grit eductors and jet pumps.

Grit Cleaning

The purpose of providing grit cleaning equipment is to remove the organic and putrescible materials settling with the grit so that the resultant product will be rela-



Wisconsin Rapids, Wisc.—Jeffrey Jigrit and Collector

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CLEVELAND 15, Hanna Bldg.
DENVER 2, 1726 Champa St.
DETROIT 13, 5808 St. Jean Ave.
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KNOXVILLE, 1848½ W. Cumberland Ave.
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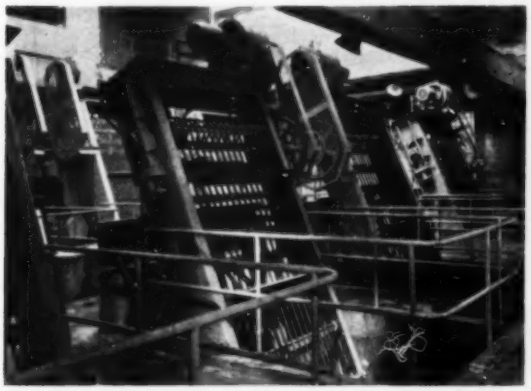
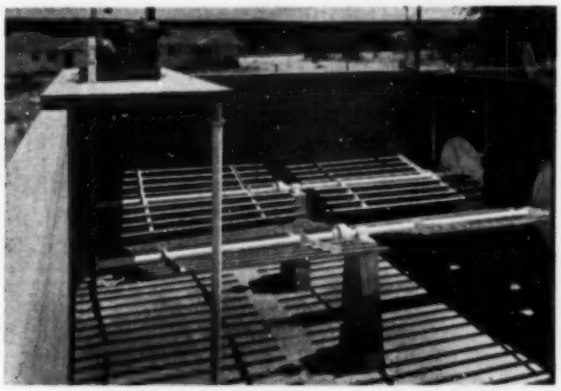
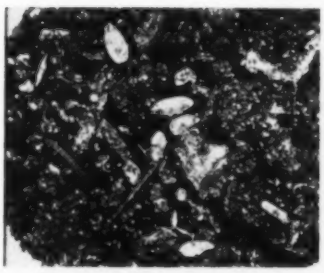
NEW YORK 7, 30 Church Street
PHILADELPHIA 3, Broad St. Station Bldg.
PITTSBURGH 22, Oliver Building
SALT LAKE CITY 1, 101 W. 2nd South St.
ST. LOUIS, Railway Exchange Bldg.



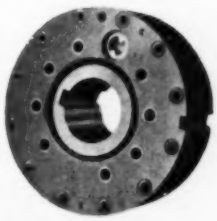
JEFFREY MECHANICALLY CLEANED BAR SCREENS: Above view shows coarse and fine back-cleaned Jeffrey Bar Screens at Owl's Head Sewage Treatment Plant, New York City. Based on new design principle, they are practically foolproof. Time control operations recommended, but operation also can be by differential float. Provision is made for continuous operation if desired. Screen bars may be of round or rectangular cross-section.



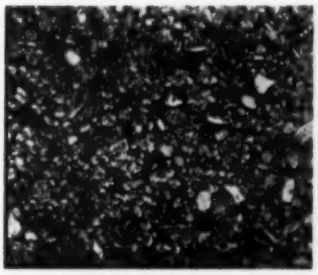
JEFFREY "FLOCTROLS": Interior view of FLOCTROL equipped basin at Big Springs, Texas, shows arrangement of paddle wheels and rotating baffles. Jeffrey offers a complete line of equipment for Water, Sewage and Industrial Waste Treatment as well as Biofiltration Systems for purification of sewage and concentrated organic wastes: Bar Screens, Grit Washers (patented), Grit and Sludge Collectors (patented), Sludge Elevators, Screenings and Garbage Grinders (patented), Conveyors, Chains and Bearings.



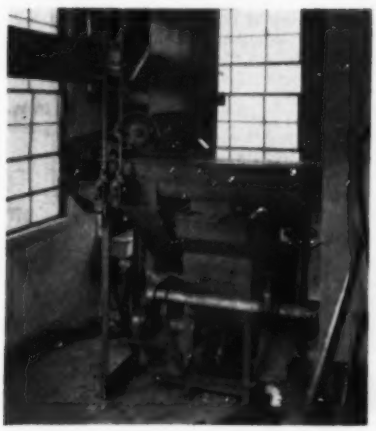
Raw grit from channel



JEFFREY "HYDROLESE": Gives positive protection against overloads for speed up to 30 r.p.m. Eliminates troublesome shear pins. Adjustable for varying loads. Has visual warning. Readily reset. Will not burn up.



Washed grit from Jeffrey "JIGRIT"



JEFFREY "JIGRIT": Produces an inoffensive washed grit that can be used for Fill, Roadways, Walkways, etc. Ends disposal problems of odors, fly nuisance and burying expense.

JEFFREY GRIT COLLECTOR AND WASHER: This large Owl's Head installation at N.Y.C. is another example of Jeffrey's Sanitary Engineering-Production "know how."

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5. Air Inlet (Vacuum Breaking) Valves Furnished in 4", 6", 8" and 10" inlet sizes, these valves eliminate possibility of collapse in thin walled pipes due to sudden drop in pressure in gravity flow lines. Float is buoyed to its seat by water pressure and upon loss of buoyancy, float falls admitting air and breaking vacuum.

6. Air Release Valves — Type AGFD air release valves vent air accumulations in pipe lines, increasing pumping efficiency and eliminating air binding at high points in line. Simple, rugged in construction, these valves are obtainable in 1" and 2" inlet sizes in working pressure to 250 p.s.i. Special valves available for pressures to 800 p.s.i.

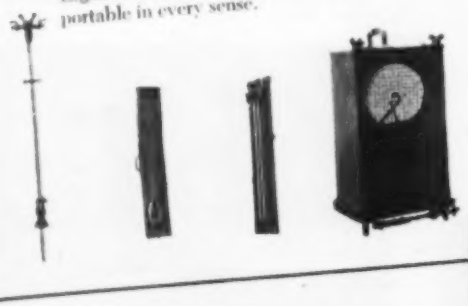
7. Type H Meter — Operates in conjunction with Venturi tubes, flow nozzles, or orifice plates on differential heads of 64 inches and 114 inches of water. Measures over respective ranges of 10 to 1 and 13 to 1 within ±2%. Wall bracket, panel mounting or floor stand, as desired. For measurement of water, air, sewage, sludge and industrial liquors. Instrument utilizes evenly spaced circular charts.

8. Flow Controllers Type "S" controllers of the Guillotine-balanced valve design are necessary units for correct filter operation. Controllers maintain constant flow regardless of variation of loss of head through filter. Sizes from 3" to 24" inclusive, they maintain control within ±3% over 5 to 1 range.

PITOT EQUIPMENT

Portable pitot rods, manometers and recorders, when used together furnish an over-all picture of actual operating efficiency of distribution systems. By their use, leaks and line breaks in grid systems are readily located.

Light in weight, compact in design, equipment is portable in every sense.



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tively free from objectionable characteristics, particularly odor.

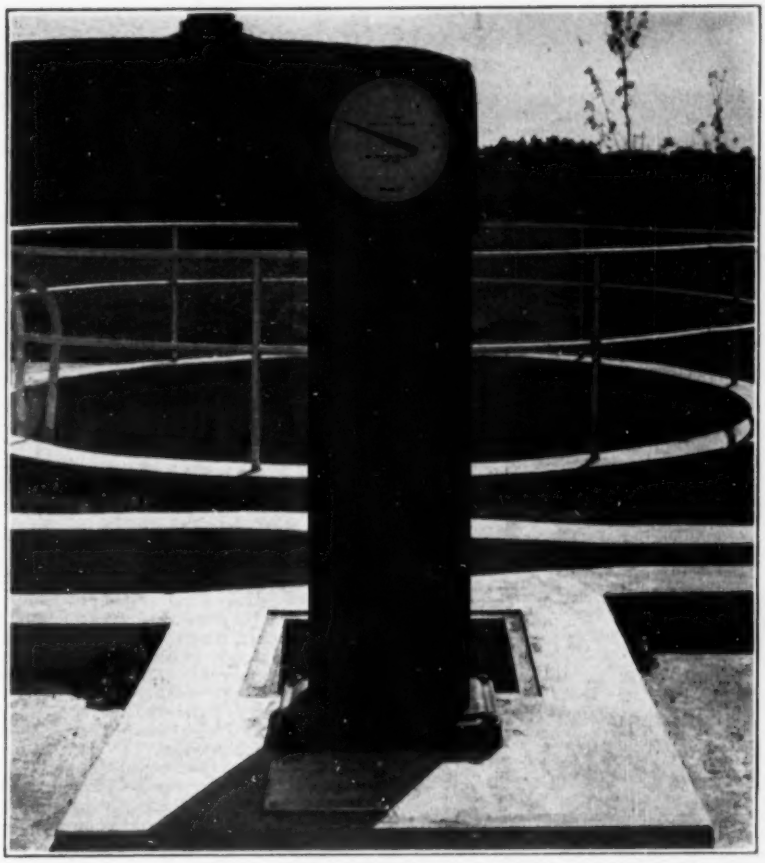
A relatively clean grit can be obtained if the grit disposal conditions make this necessary. Under ordinary conditions of grit disposal in spoil areas, grit of satisfactory quality may be obtained by one of several different processes. In many plants, satisfactory results have been obtained by returning the grit as first removed, back to the inlet of the grit channels at the surface of the flow. The grit is thus washed in the sewage flow and after washing is again removed by the equipment provided therefor.

The Dorr detritor has been described and operating data from 41 installations has been reported by Kivell and Lund.[5] The detritor grit chamber is square in plan. The grit is collected at one side of the chamber by means of scraper blades on revolving arms, and is then elevated by means of reciprocating scraper blades working on an inclined plane. The reciprocating rakes create turbulence and a back and fill motion as the grit is carried up the slope, which tend to throw light organic materials into suspension.

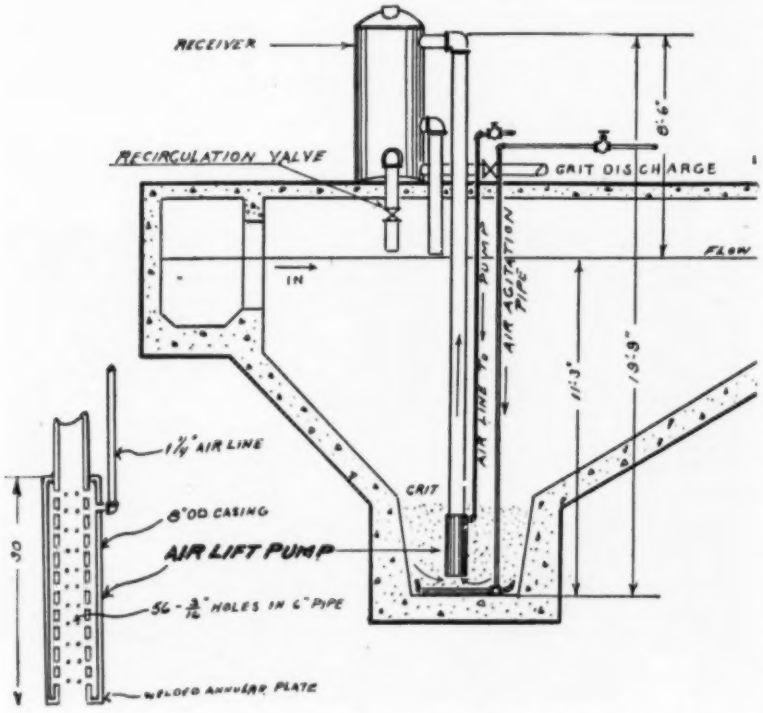
Other manufacturers recommend the use of an inclined screw conveyor for removing the grit directly from the grit channels. The Link Belt equipment at Peoria and the Chain Belt equipment at the District of Columbia are of this type.

In some plants the grit as removed from the grit channels is deposited in separate grit-washing channels equipped with either inclined screw conveyors or reciprocating rakes.

The "Jigrit" washer as manufactured by Jeffrey has been installed at several New York City plants and has been selected for the Nut Island plant in Boston and the Ashbridges Bay plant in Toronto. The grit as removed from the grit channels is discharged to the "Jigrit" for separation by stratification and washing of adhering organic solids. The principal wearing part in the washer is the diaphragm which in some instances has required replacement on the average of once each year. The early tests of this equipment at the Indianapolis plant have been reported by Nichols and Tolman.[6]



Bristol, Conn.—Builders-Providence Parshall Flume Register and Recorder

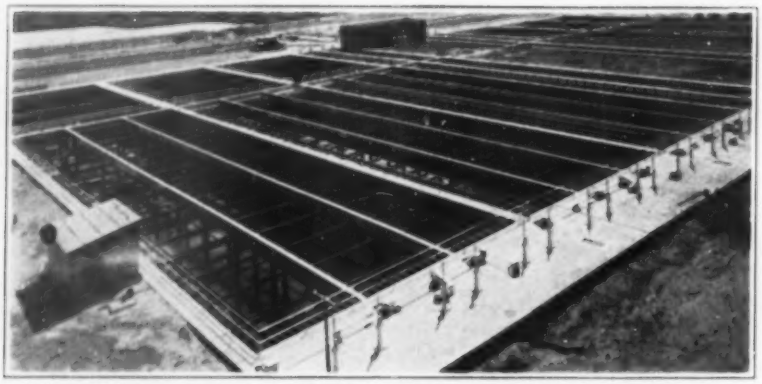


Olean, N.Y.—Details of pneumatic grit washer and ejector—After Fuller

Grit Storage

In mechanically-cleaned grit chambers of conventional design in which the grit is moved by means of flights, buckets or screw conveyors, the equipment must be operated as frequently as is required to prevent it from becoming buried in grit to the extent that it will not start up. Intermittent operation may be practical during dry weather, but frequently continuous operation is necessary during periods of storm flow. In many plants it is necessary to provide some form of grit storage facilities to act as a reservoir between the operations of grit removal and the filling of trucks to haul it away for disposal. Elevated storage bins have been quite commonly used. It has frequently been found that the grit compacts in the conical hopper bottoms of these bins above the grit draw-off gate, making it difficult to load the trucks. It has been found that air introduced to the grit bin just above the gate makes it possible for the grit to flow so that it can be drawn off readily and smoothly.

Particular attention should be given to the design and construction of gates beneath the storage bins. In several plants



Minneapolis-St. Paul—Chain Belt Rex Sludge Collectors and Automatic Skimmers

the gates installed have been difficult to operate manually and various expedients have been used, including extension of lever arms and, at one plant, by the addition of a block and tackle.

Provision should also be made for collecting and disposal of drainage from grit storage hoppers. A device consisting of a pan beneath the grit draw-off gate supported by a swiveled pipe arm which can be swung out of the way during truck-loading periods, has worked successfully.

Aerated Grit Channels

The accumulation of grit in aeration tanks, not preceded by sedimentation tanks or adequate grit chambers, has been observed for some time, particularly when the tanks have been equipped with elevated diffusers. Air has also been used in grit separation tanks in an attempt to separate out light organic materials. However, so far as we are informed, it is only recently that an attempt has been made to develop a rational basis of design for spiral flow aerated grit-separation tanks.

The apparent advantages of the aerated grit chamber as compared with other types are: (1) complicated control of velocity is not required, (2) variations of rate of flow through the chambers are of little importance, (3) the grit as removed does not require further washing for removal of organic materials, and (4) the grit can be allowed to accumulate in the grit hoppers and removed for disposal as may be convenient.

The most practical method of removal of grit from aerated grit channels will depend in part upon the size of the units. The Chicago Pump Co. has been interested in the development of the aerated grit chamber and its possible use in conjunction with pre-aeration tanks, possibly because of the use of swing diffusers in such tanks. This company has advocated the use of multiple hoppers under the diffuser system in which to collect the grit and its removal by means of jet pumps. The water used for pumping the sand would normally be plant effluent, pumped by a separate high-head pump. The grit-water mixture may be pumped to decanting tanks or grit drainage sand beds.

There is a lack of experience with this type of grit ejector so that it is not known whether it will work with satisfaction under any and all conditions. The foreseeable difficulty with the relatively small ejector nozzle and pipe is clogging with rags or other coarse materials removed with the grit.

The large scale aerated grit chamber installed at the Columbus, Ohio, sewage treatment plant has been described by Grant.[7] At this plant the grit is picked up from tank-bottom hoppers by a one-half-yard clam bucket suspended from a bridge crane with a 60-ft. span over the tanks. The bucket empties into dump trucks.

The aerated grit chambers at Columbus replace chambers of more conventional design. Except for the clam bucket there are no moving parts in the sewage so that wear and tear of equipment is reduced to a minimum.

It appears that aerated grit chambers may be used quite extensively in future designs. Their use in conjunction with pre-aeration tanks will be watched with interest. It appears desirable, for any sizable units, to provide fine mechanically-cleaned racks ahead of the aerated grit channels so as to reduce to a minimum the quantity of materials which could wrap around and collect on the diffuser tubes and air piping.

Incineration of Grit

The grit at the Buffalo sewage treatment plant was incinerated with the sewage sludge from September 1940 through April, 1941. It is reported that it was found possible to burn as high as 50 percent grit with 50 percent sludge for extended periods and occasionally for short periods to burn grit alone. However since April 1941 the grit which has about 40 percent volatile material has not been burned and has been transported to a disposal site without reported objection. According to Johnson[1] incinerating the grit caused excessive wear to equipment and caused plugging and clinkering in the ash removal system.

The grit removed at the Detroit sewage treatment plant has been incinerated in multiple hearth furnaces with the sludge cake.

The incineration of grit with screenings at Milwaukee in a multi-zone rabble furnace has been described by Lewers.[8]

References

1 John W. Johnson, Works Supt., Buffalo Authority, Sewage Works Engrg., August, 1949, p. 386.

2 American Well Works, Bulletin No. 249.

3 Grit Chamber Velocities Controlled by Parshall Flume by Stanley T. Barker, WW&S, April, 1939.

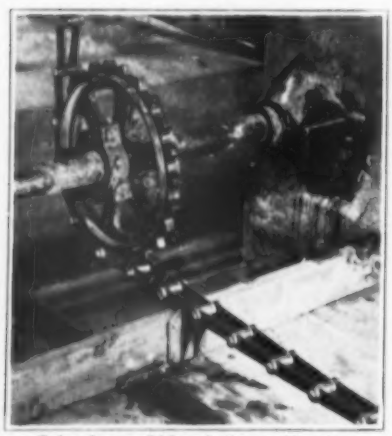
4 Nelson M. Fuller, "Pneumatic Grit Washer" N.Y., WW&S, Oct. 1942, p. 449.

5 W. A. Kivell and N. B. Lund, WW&S, April, 1940.

6 R. D. Nichols and S. L. Tolman, Municipal Sanitation, Dec. 1938.

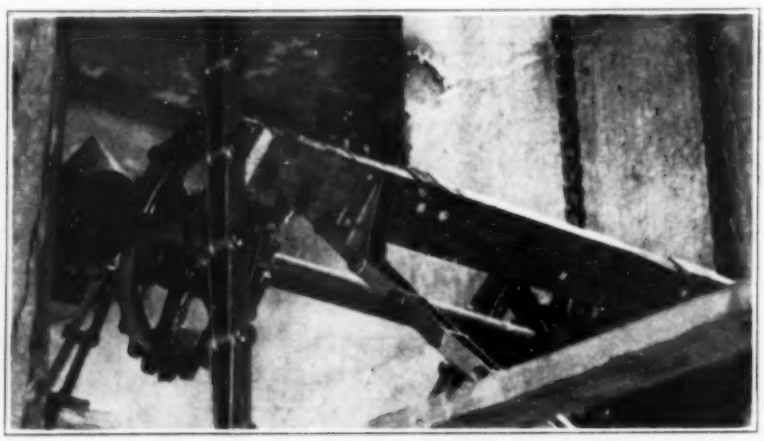
7 Nye Grant, Associate Member Paul A. Uhlmann and Associates, Columbus, Ohio. Eng. News-Rec. July 1949, p. 56.

8 George R. Lewers, WW&S, June, 1939.



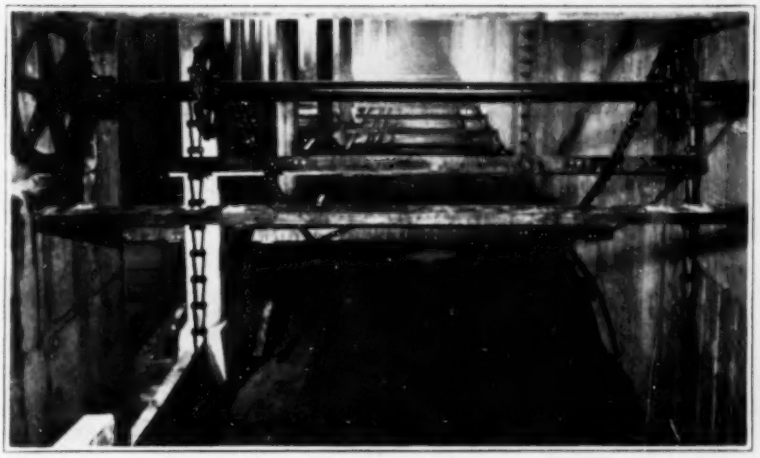
Columbus, Ohio—Jeffrey Hunting Tooth Type Sprocket

Split sprocket of alloy cast iron with chain saver rim



Columbus, Ohio—Flight equipment with full depth attachments Note insert type wearing shoes

3—Sedimentation Tanks



Toledo, Ohio—Link-Belt Straight Line Collectors

Sedimentation tanks have been designed in both rectangular and circular shape. Proponents of each design have their arguments and it is not the purpose of this article to comment on the merits of either.

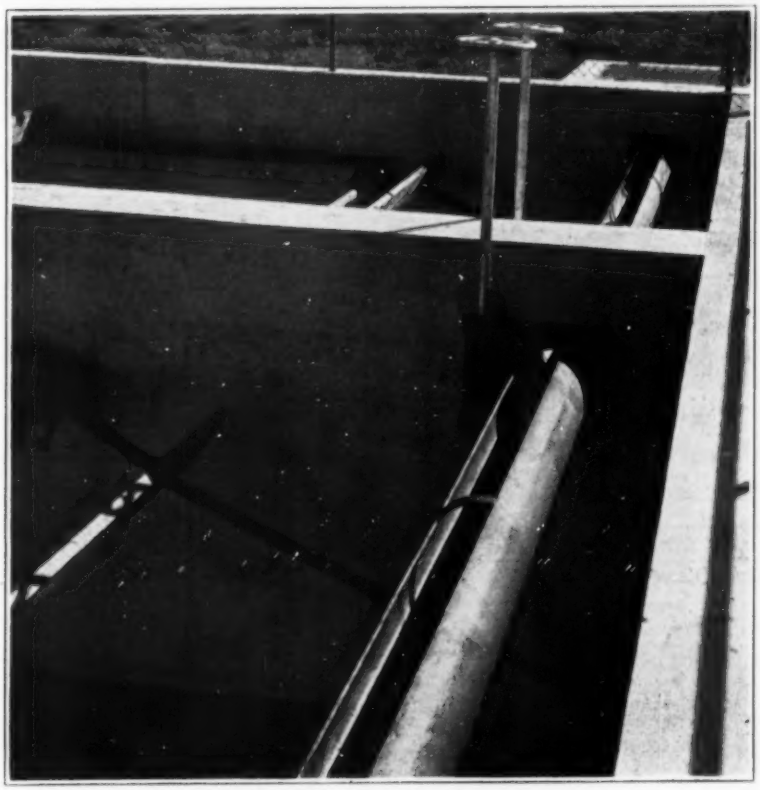
Rectangular Tanks

Equipment of this type is in a highly competitive field. For fair competition and in order to obtain the best equipment available with reasonable assurance of satisfactory operation and long life, it is desirable to specify the equipment in considerable detail. Manufacturers of this type of equipment include Chain Belt Co., Jeffrey Manufacturing Co., Link Belt Co., and Walker Process Equipment Co.

Chain and Flight Construction

Mechanisms include chains, flights, sprockets, shafts, and drive unit. The chains should be rugged and durable. Specifications commonly require that the chains be for the pintle type and made of processed malleable iron such as "Supermal," "Promal" or "Z-metal" with an ultimate tensile strength of not less than 70,000 psi. (pounds per square inch). The required working strength of the chain can be readily determined by consultation with the manufacturers and should be included in the specification so that all will quote on the same basis. Chains have been supplied with copper-bearing riveted steel pins. There is evidence that these pins wear and produce excessive elongation resulting in wear on the sprockets. Recently some of the manufacturers have recommended that the pins be of hardened steel.

Attachments for the chains to the flights at one time were commonly designed for bolting to part depth of the flight. There has accumulated some evidence of the flights splitting, under this condition, longitudinally beyond the attachments. Some manufacturers recommend a full depth flight attachment in order to strengthen the flights against this splitting. Because of the competitive situation, it is necessary to specify the full depth attachment if it is desired.



Bristol, Conn.—Skimming pipes for scum removal

Flights are commonly specified to be of redwood. For the smaller tanks, sizes of 1⅝ by 5⅝ in. dressed, are suitable. For some of the larger tanks sizes of 2⅜ by 7⅝ in. dressed, appear advisable. The flights ride on rails embedded in the bottom of the tank for the collection of sludge and upon angles supported from the sides of the tank for the return flight. Wearing shoes are provided on the flights. Johnson[1] reported that replacement of these wearing shoes caused excessive labor and expense and recommended removable wearing shoes as illustrated in Fig. 1 of his paper. We have adopted this as standard construction and our specifications require that "The flights shall be provided with chilled cast-iron wearing shoes inserted into malleable-iron holders bolted to the flights at points of contact with rails in the tank bottom and with supporting angles." The castings must be of such workmanship that the removable shoe will not shake loose during ordinary operation of the flights.

At the Minneapolis-St. Paul sewage treatment plant as reported to the writer by Kerwin L. Mick, Chief Engineer and Superintendent of the plant, the best answer to the shoe-wear problem, under the conditions at that plant, is the application by welding of two "Stellite" strips about ⅜ in. wide and about 2 to 2½ in. apart on each shoe. He reports that the wear on the bottom rails set in the concrete is not excessive and when it does occur, the situation is easily remedied by spot welding flat steel strips on top of the original rail. Some of such work was required in 1947 after seven years of operation with the "Stellite" strips.

Material improvements have been made in the sprockets. The "hunting tooth" or "extended life" sprockets are claimed to reduce wear on sprockets by about 50 per cent. Several of the manufacturers have agreed that it is desirable to specify sprockets of alloy cast iron with a nickel content of 1.00 to 1.25 per cent and a chromium content of 0.45 to 0.65 per cent. The sprockets should be chilled to give them a hardened tooth surface.

Recently a survey was made of chain-and-flight type sludge collectors in primary sedimentation tanks at 10 sewage treatment plants in New England with from 9 to 16 years' operating experience. There were 49 individual longitudinal collectors operating on the average for 11 years. The aggregate experience in repairs and replacements for all of this equipment is as follows:

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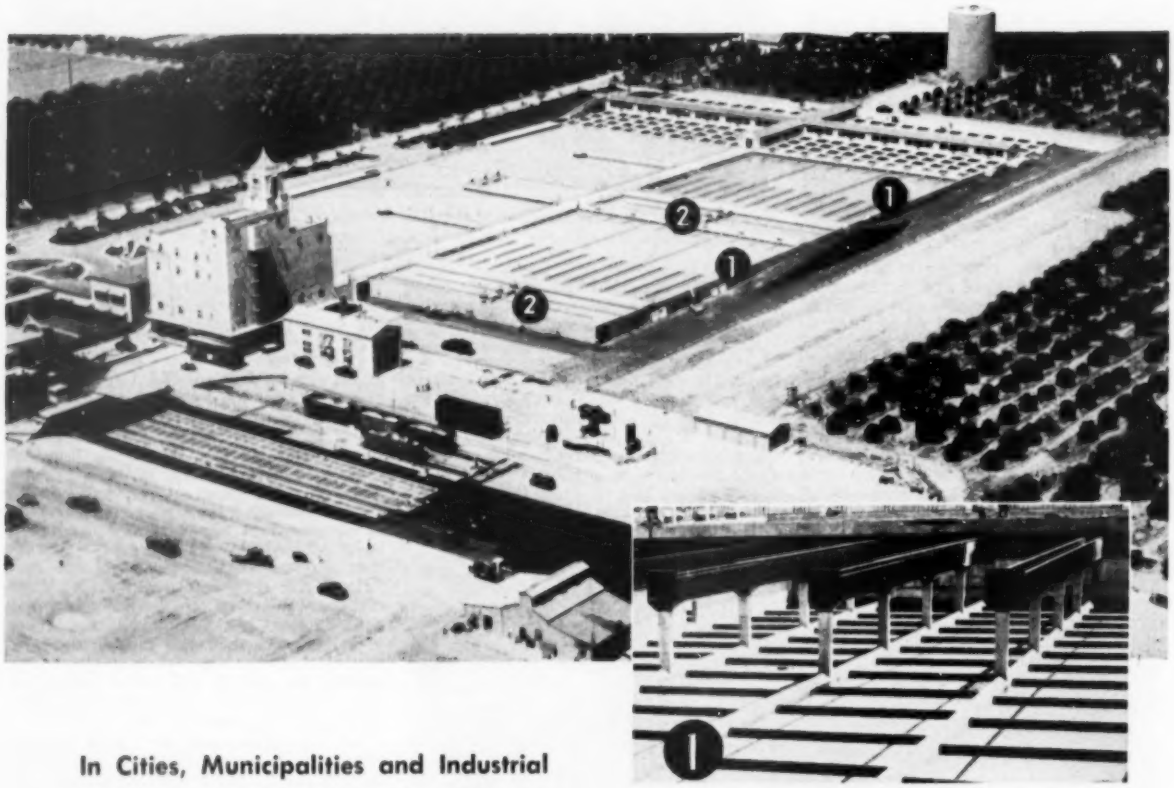

Straightline Collectors

Two 200 x 200 ft. settling tanks at La Verne, California, have Straightline Collectors indicated by No. 1. Peak-cap bearings, pivoted flights, and "Straightline Action" mean top efficiency.

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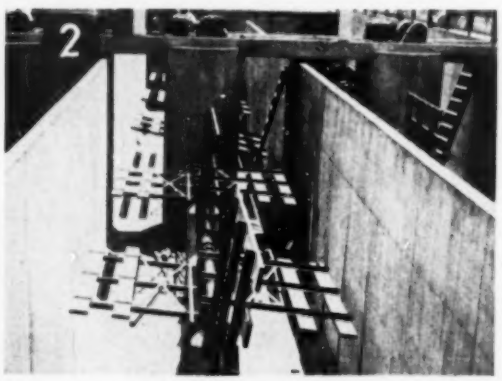
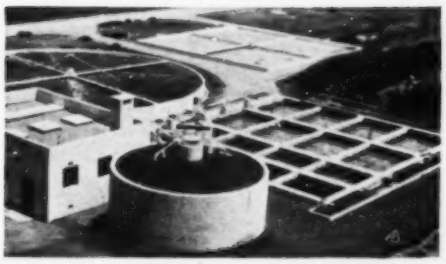


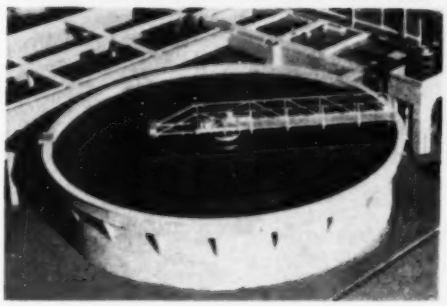
Straightline Mixers

Straightline Paddle Mixers (No. 2 above) provide gentle rolling action in two 48 x 200 ft. mixing tanks. Drive units for all tanks are Link-Belt Electro-Fluid Drives with "Cushion Action."



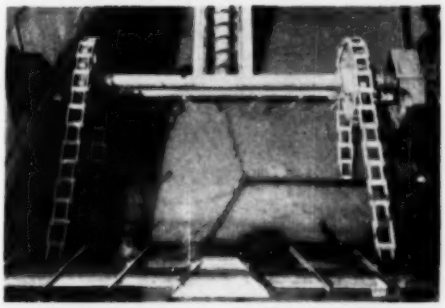
◀ Bio-Filtration Systems
This system consists of high rate shallow filters and recirculation of the effluent from the filter to the settling tanks, in single-stage or two-stage treatment, as required.

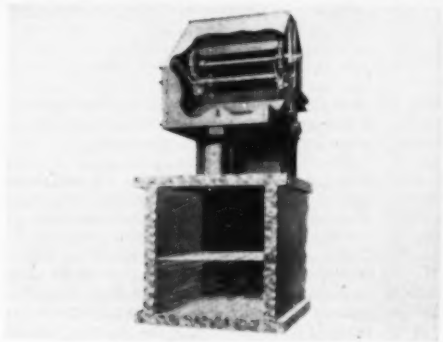
Scum Breakers ▶
Used in either round or rectangular digestion tanks to break up the floating scum, and to paddle down and submerge it.



◀ Circuline Collectors
"Straightline Action" assures quick and positive sludge removal from the entire tank floor in one revolution.

Grit Collectors and Washers ▶
Effectively collect, wash and remove settled grit and separates it from putrescible organic matter.





Thru-Clean Bar Screens

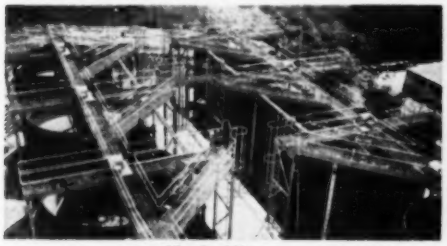
A coarse bar rack and chain operated rakes equipped with fingers that clean thru the rack from the back. The screen cannot be jammed by large objects since the rake will enter under and lift them.

Straightline Bar Screens

For removal of floating solids over ½" in size, from incoming sewage or industrial liquids, thus protecting the equipment in the following plant units.

Tritor Screens

For the removal of screenings and grit at small sewage treatment plants. With the Tritor Screen, one mechanism accomplishes removal of both grit and screenings.



Flash Mixers

For rapid and thorough mixing of chemicals with water, sewage or industrial liquids. A large four-blade propeller operates without under-water bearing.

Liquid Screens

An efficient and economical screen for the removal of solids from industrial liquids. Units are available in several sizes with coarse or fine screen medium.

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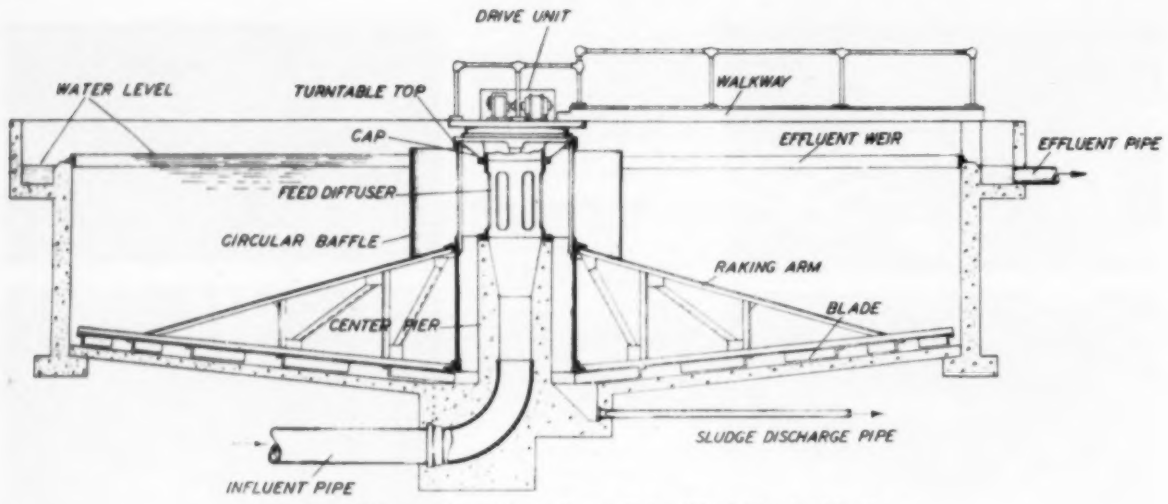


Cleveland, Ohio—Design of Dorr Center Drive Sifeed Circular Clarifiers

Drive chains, replaced in 2 tanks after 10 years of operation, a few links and pins replaced in 7 tanks.

Drive sprockets; 2 replaced.

Idler and take-up sprockets; 1 replaced, 1 redrilled.

Main chains; 1 broken link.

Flights; total of 20 replaced at 9 plants, replaced as broken at tenth plant with no record.

Flight shoes; no replacement at 7 plants, replaced after 11 years at 1 plant, replaced every 3 years at 1 plant and 12 individual replacements in 16 years at 1 plant.

Omitting one plant which operates the equipment continuously 24 hr. per day, the indicated life of the various parts, as reported by the operators, is 10 to 21 years for drive chains, 14 to 26 years for drive sprockets, idlers, and take-up sprockets, 13 to 24 years for main chains, 10 to 26 years for flights, and 3 to 19 years for flight shoes.

Mick of Minneapolis-St. Paul San. Dist., reports to the writer that all of the original main sludge collector chains in the Minneapolis-St. Paul sewage treatment plant sedimentation tanks placed in operation in 1938 are still in use. On two of the tanks, the chain would soon be worn through the barrel but it is planned to turn this chain over before that happens. The wear will then come on the other side of the barrel and it is expected that the life of the chain will be prolonged several years thereby.

Experience has disclosed that the life of the equipment may be prolonged and the cost of renewals and repairs reduced by operating the equipment in primary settling tanks for a few hours each day during sludge withdrawal operations. In small plants, chains and shoes which may require replacement at the end of 10 years for equipment operating 24 hours per day should last from 15 to 20 years if operated 1 to 3 hr. per day. For the largest plants more frequent replacement may be required.

Chain-and-flight construction is particularly adapted to covered sedimentation tanks as at Detroit, Boston Nut Island, Toronto Ashbridges' Bay, Los Angeles Hyperion primary settling tanks, among the larger plants; and Greenwich, Connecticut; Tonawanda, New York; Greenfield, Massachusetts; and Warren, Rhode Island, among the smaller plants. This type of construction is also advantageous for rectangular tanks in which it is desirable to remove the sludge rapidly and continuously so as to avoid deterioration in its quality.

Overload Release

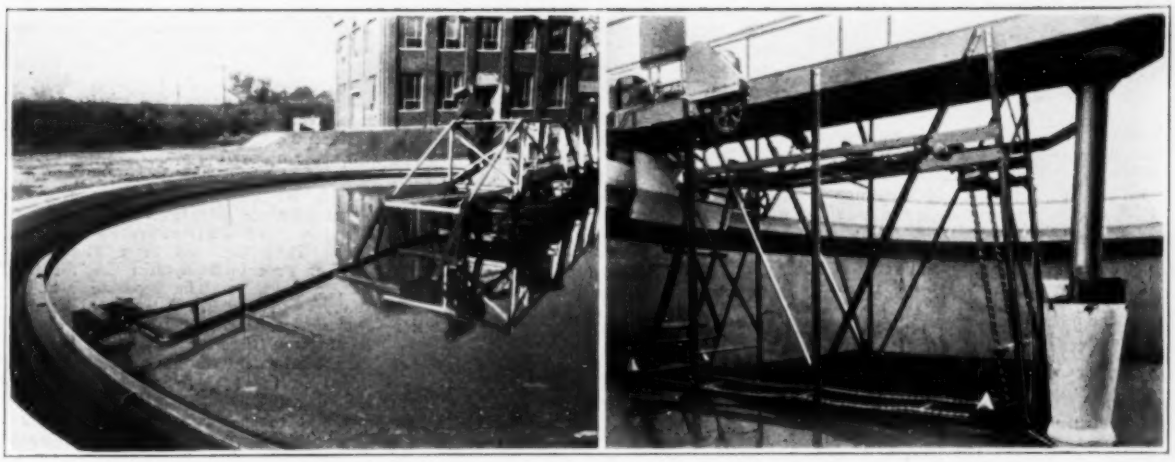
The most common method of providing against damage to the equipment because of overload is by shear pins. However, if a shear pin breaks because of overload the temptation is strong to put in a stronger pin and attempt to get the equipment moving rather than to unwater the tank and find out the cause of the overload. Major damage to equipment has been caused by the substitution or use of improper shear pins.

Several adjustable overload release devices have been developed to mechanically disengage the collector from the motor when overloads are encountered.

The Chicago Sanitary District is well satisfied with the operation of individual motorized reducers on sludge collectors. The basis of this design has also been described by Johnson.[1] All parts except the flights are designed to withstand the torque of the motor. Consideration must be given to the motor size and to selecting characteristics such that the maximum torque is not materially greater than the running torque. Particular attention should be given to possible deflection of shafts and consequent effect on bearing mountings. Self-aligning bearings are helpful to prevent difficulties of the latter type.

It appears advisable to specify that bolts shall not be less than ½ in. diameter and structural steel shapes shall have a thickness of not less than ⅜ in.

Topeka, Kan.—Chain Belt Tow-Bro Sludge Removers



Link-Belt "Circuline" Clarifier and Skimming Mechanism

Sludge Hoppers

Multiple hoppers for collection of sludge at the ends of rectangular tanks have caused operating headaches as the sludge tends to collect and hang up on the sides and in the corners. In time, this sludge becomes gas lifted and belches to the surface. The operator afflicted with this type of tank must spend considerable time pushing the sludge down to the bottom of the hoppers where it can be picked up by the pump suction. Even in relatively narrow tanks it appears advisable to provide cross collectors so that insofar as is practical, sludge is brought to the drawoff piping mechanically. In small tanks where longitudinal chain and flights have been used to collect the sludge at the ends of the tanks, it has in some instances proven practical to install cross collectors of the spiral conveyor type.

Scum Removal

Various types of mechanisms have been devised for withdrawal of scum from rectangular tanks equipped with chains and flights for sludge and scum collection. The rotated slotted pipe provides a simple means for manual control of scum withdrawal. (See acompanying cut for Bristol, Conn.) Where such manual control is too laborious it is possible to use mechanical means. One of the simplest mechanical skimmers consists of a rotating spiral squeegee which carries skimmings up a launder and discharges them into a scum trough, whence they are transmitted by water carriage to the disposal facilities. This type has been provided for the Los Angeles Hyperion primary settling tanks.

At the Boston Nut Island plant provision is made for conveying the scum while still floating on the sewage to one scum storage sump for each of two large rectangular tanks. The equipment is of the chain-and-flight type.

Crane-and-Bridge Type

Prior to 1939, the policy of the Dorr Co. was to recommend circular clarifiers wherever possible. As competition developed for their equipment in the circular tank field and as rectangular tanks with common walls were often preferred by some engineers under certain circumstances, the Dorr Co. developed and advocated the Monorake for sewage sludge removal from rectangular sedimentation tanks. This equipment was originally developed by them primarily to meet the need for mechanical removal of sludge from sedimentation tanks following "flocculators" in water treatment plants. The Monorake type of sludge removal equipment is reported to be available for rectangular sedimentation tanks up to 60 ft. wide and any reasonable length. This type of equipment includes a balanced raking mechanism supported and operated from a carriage spanning the width of the tank and traveling on longitudinal rails. The carriage is operated by cables. The rakes are so set as to collect the sludge in one or more hoppers at the influent end of the tanks. The first large installation of this type was at the Coney Island plant in New York about eight years ago. The principal difficulty encountered has been with failure of the reversing switch to operate. It is understood that the manufacturer has improved the design in this respect. The average life of the cables at this plant is said to be about five years. Other items of equipment requiring occasional replacement are cable sheaves, flight shoes, carriage wheels, and bearings.

One of main advantages of this type of mechanism is that the amount of equipment immersed in the sewage is reduced to a minimum and all equipment can be raised above the sewage level for renewals and repairs. Thus it is not necessary to unwater the tank for such work.

The Hardinge Co., Inc., makes sludge removal equipment for rectangular tanks consisting of a bridge crane which spans the width of the tank and supports the sludge scraper and skimmer. The sludge is collected in one or more hoppers at the influent end of the tank or in a trough equipped with a cross screw sludge conveyor.

Circular Tanks

The Dorr Co. has been the outstanding manufacturer of sludge removal mechanisms for circular sedimentation tanks. Also in this field are Hardinge Co., Yeomans Brothers Co., Infilco, Inc., and Chain Belt Co.

In the Dorr Type S clarifier, feed is introduced through a centrally located, inverted siphon with the inlet surrounded by a submerged diffuser. From the center inlet, the sewage flows radially to a peripheral weir. A motor-driven revolving rake sweeps the settled solids to a central discharge hopper in the tank bottom. Representative installations include the primary settling tank at the District of Columbia and the final settling tanks at the Cleveland Easterly plant. L. M. Johnson[1] has described the advantages gained by the use of stalling torque motors to drive equipment of this type at the plants in the Chicago Sanitary District. The clarifiers in the 126-ft. diameter final settling tanks at the Chicago Southwest plant are driven by ½-hp. motors through 69,500 to 1 combination helical and spur-gear speed reducers. The motor constitutes the only protective device throughout the entire gear train.

Tanks of this type afford only a small hopper for sludge accumulation. For the Dorr clarifier at the Terminal Island plant in Los Angeles, the operators report that it is desirable to provide automatic programmed intermittent operation of the raw sludge pumps in order to withdraw reasonably well concentrated sludge.

In very large circular final settling tanks, wind currents and high rates of weir discharge for a single peripheral weir have been reported to induce the discharge of unduly large quantities of suspended solids with the tank effluent. The unit weir discharge rates may be substantially reduced by the provision of supplementary weir capacity in connection with an effluent trough built within the tank and supported from the outside wall.

There is evidence to show that, on the average, the cost of maintenance, renewals, and repairs on sludge removal equipment in circular tanks is relatively low.

The sludge withdrawal pipelines from circular tanks are of necessity longer than for rectangular tanks. There is very little evidence to show that this has caused unusual operating difficulties except at the Buffalo plant. Here the sludge withdrawal lines became plugged with grit and heavy sludge to a serious extent as reported by John W. Johnson.[2]

Various devices have been developed for collection of scum on the surface of circular primary sedimentation tanks. The collection is sometimes effected by wind currents. Several instances have been observed where the operators have improved upon the standard form of scum collector supplied by the manufacturer but the improvements have not been described in the technical literature.

References

1 L. M. Johnson, Mun. Sanit., Nov. 1938, p. 529.
2 J. W. Johnson, Sew. Wks. Engr., Aug. 1944, p. 386.

4—Sludge Digestion Tanks

Considerable mechanical equipment is usually involved in modern separate sludge digestion systems. Among the more important items requiring consideration are, floating covers, gasometer-type covers, fixed steel covers, heating systems, sludge removal, recirculation systems, gas collection, supernatant withdrawal and scum control.

Floating Covers

John R. Downs, Superintendent of the Joint Meeting Sewage Treatment Plant at Plainfield, N.J., is credited with the design of the first floating cover for a separate sludge digestion tank in the United States. The simple wooden cover designed by him has been developed by the Pacific Flush Tank Co. into a modern mechanism built of steel with guides, controls, supernatant selectors, pressure and vacuum relief valves, gas domes, manholes, sampling hatches, level indicators and other appurtenances. The original floating cover patents have expired and other companies now compete for the floating cover business. This relatively new competitive condition places a responsibility on the engineer to draw up plans and specifications which will assure truly competitive bidding and that his client will receive equipment which will meet the requirements for service and long life.

The engineer is also responsible for weighing the costs and comparative advantages and disadvantages of the floating covers with gasometer and fixed covers of various types and forms.

There has been some experience with tilting of covers with resultant jamming and some damage to the equipment. Guides and extended rollers have been used in some instances for the purpose of controlling tilting.

Under certain conditions floating covers have been known to freeze in a fixed position for several weeks at a time. Heat has been applied to the annular ring between the cover and the tank walls to correct this condition.

The natural weight of the floating cover may not provide the desired gas pressure. In some instances weight has been added to the cover to increase the gas pressure.

The floating covers ride on the liquid surface or scum. Provision should be made to prevent the rapid loss of heat through the cover. This can normally be accomplished by covering the roof over the ceiling plate with corkboard, foam glass or other insulating material. The insulating material should be protected by roofing. In some instances heat has been applied to the air space between the ceiling plate and roof in order to heat the top of the digestion tank[2].

Gasometer Type Covers

The gasometer type of cover has been extensively used by the Dorr Co. in the secondary tank of its so-called Mult-digest system. It is also quite commonly used where engineers desire a relatively small volume of gas storage and find it convenient to provide this at a digestion tank, or a sludge storage tank, rather than in a separate holder. The depth of gas storage under the gasometer cover is usually on the order of 2 to 6 ft. or more. The Dorr Co. has used a center column and Pacific Flush Tank Co. has used a spiral guide, to prevent tilting of the gasometer cover.

Fixed Steel Cover

The Dorr Co. has commonly used a fixed-steel cover on the roofs of primary digestion tanks in its Mult-digest system. Competitive bids between fixed steel domes and fixed concrete roofs for the large digestion tanks at the Los Angeles Hyperion Plant in 1948, favored concrete dome roofs.

Heating Systems

For about 20 years prior to 1947, the majority of digestion tanks were heated by means of hot water circulated in coils within the tanks. These installations if designed with ample area and operated at relatively low temperature of hot water, if constructed of suitable materials and joints, if adequately supported and if not seriously affected by electrolytic action, have given very satisfactory service. There are enough "ifs" in the design, construction, and operation of those heating coils so that failures have been recorded.

Recently the tendency has been away from the use of hot water coils inside the tanks towards enclosed heat exchangers outside the tanks. This has been promoted in part by the sales efforts of the manufacturers, particularly at first by the Pacific Flush Tank Co. and more recently by Walker Process Equipment Co., the Dorr Co., and others. The separate heat exchangers are usually designed to heat the raw sludge being admitted to the tank or liquor circulated from the tank. In the latter case, the heated recirculated liquor may be added to the raw sludge for rapid conditioning.

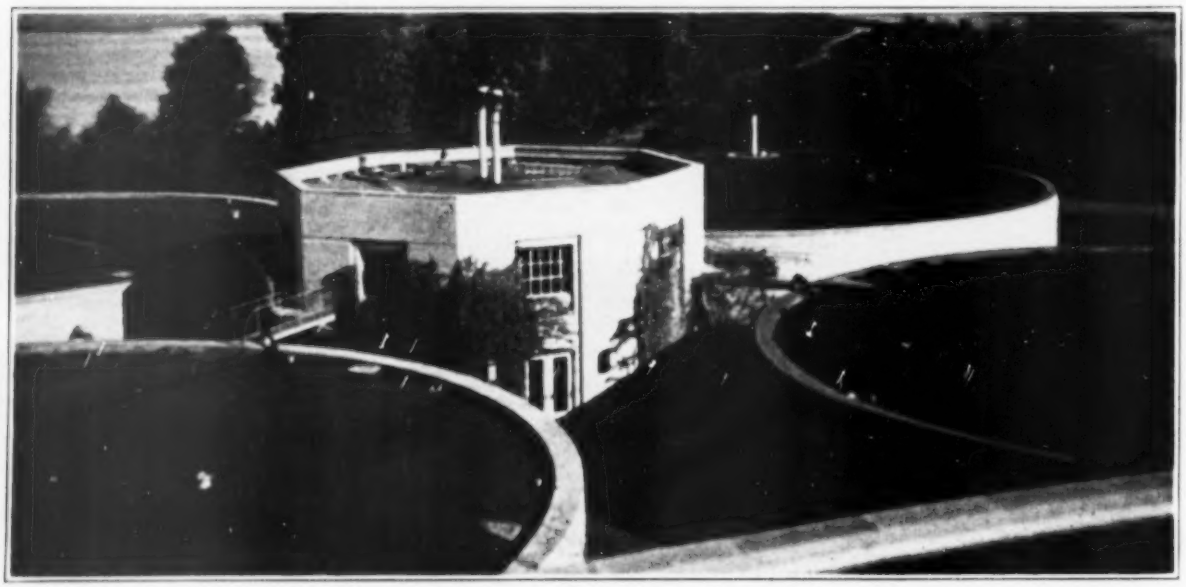
Direct contact combustion heaters have been installed in the digestion tanks at Baltimore[3] and at Philadelphia[3] and the control of temperature in digestion tanks with live steam has been described by Rawn[4].

The digestion tanks at the Los Angeles Hyperion plant are heated by means of steam admitted into the flow tube below the impellers of Dorr mixers. The steam is reclaimed from the vapor phase system at the dual fuel gas diesel engines. Where direct steam heating is used, the water should be treated as required to prevent operating difficulties at the steam boilers.

Infilco, Inc. has developed a so-called "Verti-Flo" impeller for installation in the scum zone of digestion tanks. Heating coils are installed at the mixer in a vertical bank which can be withdrawn through a manhole in the roof.

Scum Control

Possibly the greatest single difficulty experienced with the operation of sludge digestion tanks has been in accumulation of masses of relatively inert scum which renders ineffective a substantial proportion of the tank capacity, clog supernatant and overflow pipes, and create numerous operating problems. It appears that if the scum



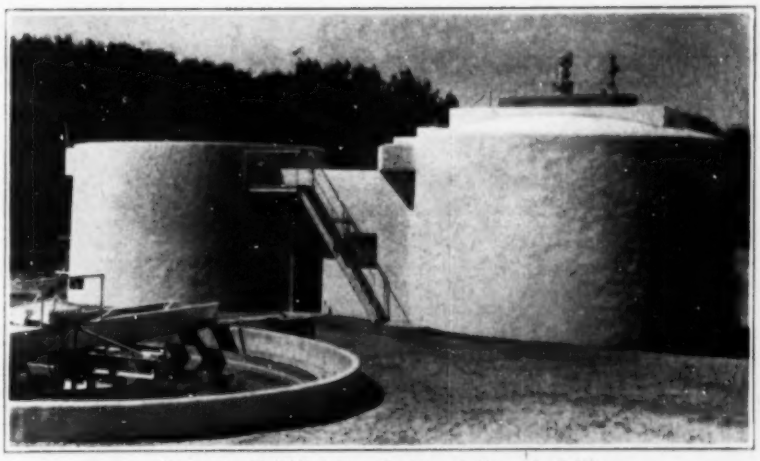
Separate sludge digesters with P.F.T. Floating Covers—Buffalo, N.Y. Sludge control house, center, has P.F.T. heat exchangers, control devices, and pumps

is kept well mixed with warm tank liquors, the scum-forming materials will continue to digest and for the most part settle to the bottom with the sludge. If well lubricated by tank liquors, excess accumulations of floating materials can be withdrawn through piping connections in the upper portion of the tank.

Several schemes have been developed designed to meet the scum problem. A few will be briefly described. In tanks equipped with floating covers, the Pacific Flush Tank Co. recommends the installation of a circulation system designed to produce a flow and mixing action at the center of the tank in the gas dome. In theory, scum accumulating under the floating cover and outside the limits of the gas dome will flow into the center and receive treatment.

The Dorr Co. recommends the installation of propeller mixers installed in the scum zone below the roofs of fixed-roof tanks. These are designed to mix the scum with the underlying tank liquor. Favorable results have been reported with this equipment at Stamford, Conn. Units of this type have been installed in the digestion tanks at the Hyperion Plant in Los Angeles. Where particular types of industrial wastes conducive to the formation of very heavy scum masses are to be encountered, this company has recommended mechanical mixers with slowly revolving stirring arms passing between fixed teeth suspended from the roof. Similar equipment is supplied by Hardinge Co., Yeomans Bros. Co., and Infilco, Inc.

For circular fixed roof tanks, the author[5] has recommended the circulation of liquor at relatively high rates, the liquor being drawn from beneath the scum zone and discharged just above the normal liquid or scum level. Four discharge nozzles are provided located at about quarter points in plan and inclined at about 45°, directed so as to cause a circulatory motion in the scum and to bring scum not directly under the nozzles into the active turbulent mixing areas. An installation of this type on a primary digestion tank, 50 ft. in diameter, at Bristol, Conn., has proven very effective in quickly eliminating a mass of heavy scum which formed during the early weeks of operation before the circulating liquor was discharged through the scum nozzles above the liquor level. After this heavy scum was eliminated, it has been found practical to restrict scum accumulation to a relatively thin soft layer by operating the recirculation system a few hours each day.



Dorr Co. Multidigestion System at Carmel, Calif.

For square or rectangular tanks, the Link-Belt Co. makes a scum breaker which consists of a number of paddles attached to a pair of endless chains moving through the scum at a speed of about 1 fpm. The return flight is through the mid depth of the tank.

Sludge Removal Mechanisms

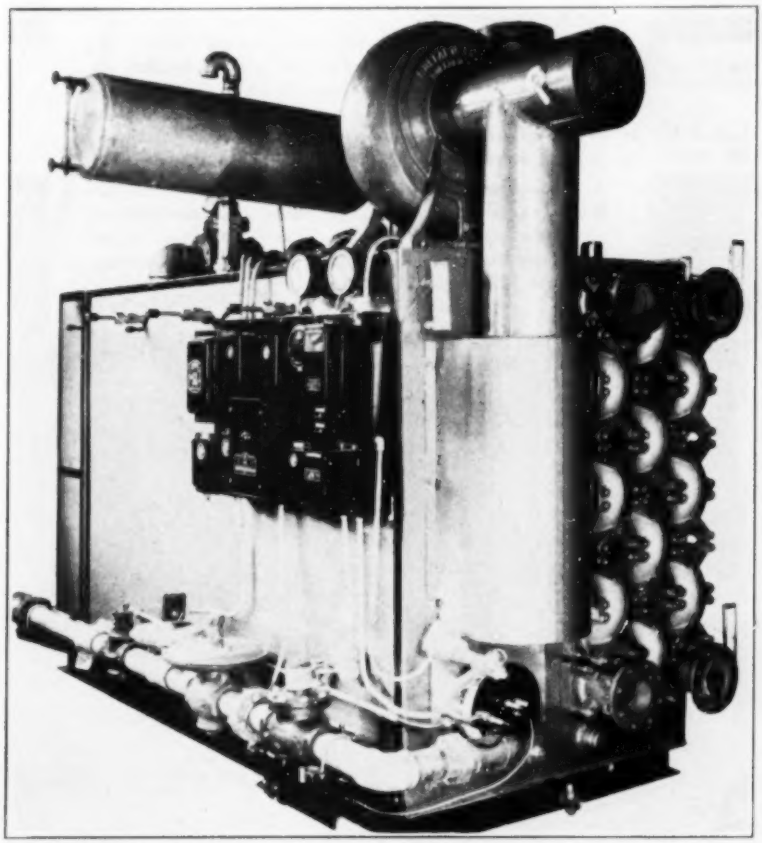
In the earlier designs, digestion tanks were equipped with sludge removal mechanisms similar to those provided for circular and rectangular sedimentation tanks. The operation and maintenance of this equipment proved to be difficult and expensive. Recently circular tanks have been provided with inverted conical bottoms to promote the withdrawal of sludge without the aid of mechanical equipment. Relatively few rectangular digestion tanks have been built or proposed during the recent years.

Supernatant Withdrawal

Normally as raw sludge digests there is a separation of relatively dilute liquor from the concentrated sludge or scum. This dilute liquor usually collects over the bottom sludge and under the scum layer. In the majority of plants multiple pipe connections are made to the tanks in the zone where dilute liquor is most apt to collect and provision is made for supernatant withdrawal by selection after sampling to determine where the clearest liquor may be obtained.

The new tanks at the Hyperion plant in Los Angeles are equipped with a swivelled supernatant withdrawal pipe operated by means of a cable and winch rigging. The cable passes through the tank roof by means of a Varec fitting designed for a 12-in. water seal.

The Pacific Flush Tank Co. advocates the use of its "Supernatant Selector." This consists of a slotted tubular device mounted vertically at the central portion of the digester and extending throughout the portion of the depth from which supernatant is normally withdrawn. The tube is made with slots that are intended to be sufficiently narrow to hold back liquid containing large amounts of suspended solids and to pass the clearer liquid for withdrawal from the tank. Provision is recommended for backflushing as needed to clear the slots.



P.F.T. Hot Water Type Heater and Heat Exchanger—Stockton, Calif.

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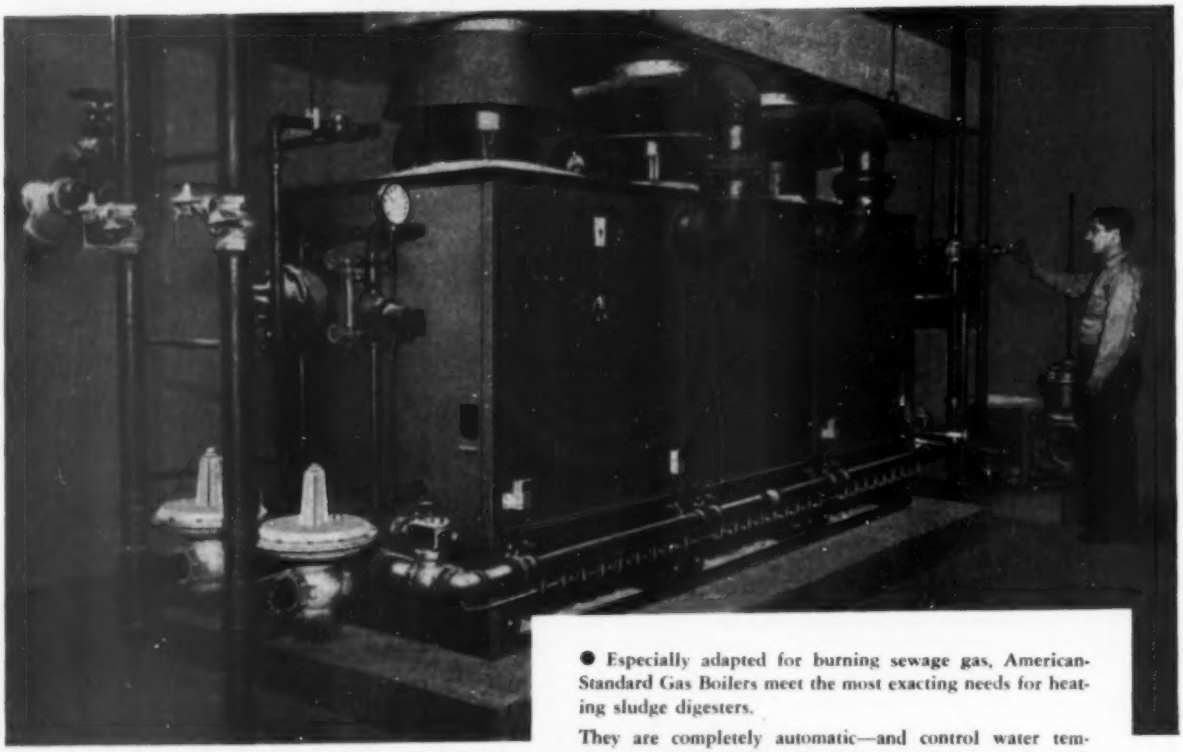

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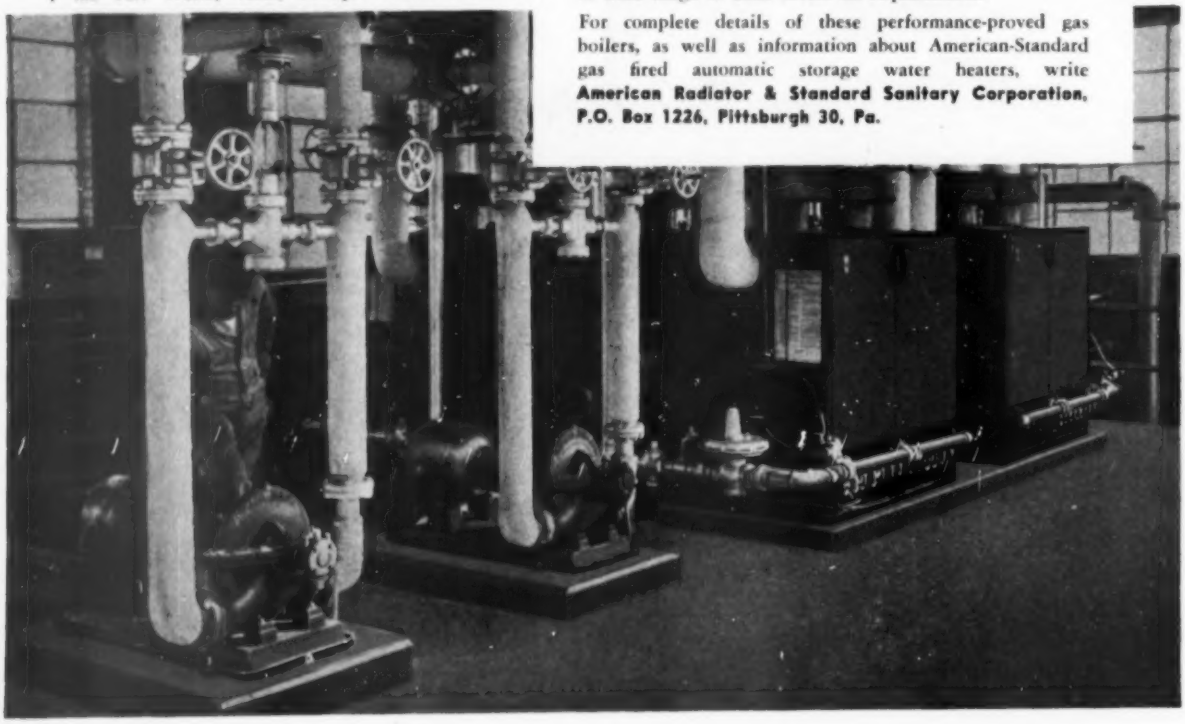

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BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU per Hour	Cu. Ft. 700 BTU Sludge Gas	Overall Hgt. xx	Floor Space Width	Floor Space Depth
	1-GA-4E	31,500		210	39,375	56	40 1/2"	16	19 1/4"
	1-GA-5E	42,000		280	52,500	75	40 1/2	16	22 1/4
	1-GA-6E	52,500		350	65,600	94	40 1/2	16	25 1/4
	2-GA-4E	63,000		420	78,750	113	54 3/4	16	19 1/4
	2-GA-5E	84,000		560	105,000	150	54 3/4	16	22 1/4
	2-GA-6E	105,000		700	131,250	188	55 1/2	16	25 1/4
	2-GA-7E	126,000		840	157,500	225	55 1/2	16	28 1/4
	4-GA-8E	147,000		980	183,750	263	54	16	37 1/4
	4-GA-9E	168,000		1,120	210,000	300	54 1/2	16	40 1/4
	4-GA-11E	210,000		1,400	262,500	375	54 1/2	16	46 1/4
0-GS-4E		61,200			76,500	109	53 1/8	16	33 3/4
0-GS-5E		81,600	255		102,000	146	53 5/8	16	37 3/4
0-GS-6E		102,000	340		127,500	182	54 1/8	16	41 3/4
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1-GS-5	1-GW-5	192,000	600	960	240,000	343	59 3/4	23	25
1-GS-6	1-GW-6	240,000	800	1,280	300,000	429	60 1/4	27	25
1-GS-7	1-GW-7	288,000	1,000	1,600	360,000	517	62 3/8	31	25
1-GS-8	1-GW-8	336,000	1,200	1,920	420,000	600	63 1/4	35	25
1-GS-9	1-GW-9	384,000	1,400	2,240	480,000	686	65	39	25
1-GS-10	1-GW-10	432,000	1,600	2,560	540,000	771	65 5/8	43	25
4-GS-6	4-GW-6	480,000	1,800	2,880	600,000	857	74 7/8	27	41 1/2
4-GS-7	4-GW-7	576,000	2,000	3,200	720,000	1029	76 5/8	31	41 1/2
4-GS-8	4-GW-8	672,000	2,400	3,840	840,000	1200	78 1/8	35	41 1/2
4-GS-9	4-GW-9	768,000	2,800	4,480	960,000	1372	79 7/8	39	41 1/2
4-GS-10	4-GW-10	864,000	3,200	5,120	1,080,000	1573	81 1/2	43	41 1/2
4-GS-11	4-GW-11	960,000	3,600	5,760	1,200,000	1715	83	47	41 1/2
4-GS-13	4-GW-13	1,152,000	4,000	6,400	1,440,000	2060	76 5/8	31	41 1/2
4-GS-15	4-GW-15	1,344,000	4,800	7,680	1,680,000	2400	78 1/2	35	41 1/2
4-GS-17	4-GW-17	1,536,000	5,600	8,960	1,920,000	2740	79 7/8	39	41 1/2
4-GS-19	4-GW-19	1,728,000	6,400	10,240	2,160,000	3086	81 1/2	43	41 1/2
4-GS-21	4-GW-21	1,920,000	7,200	11,520	2,400,000	3425	83	47	41 1/2
4-GS-22	4-GW-22	2,016,000	8,000	12,800	2,520,000	3600	78 1/2	31	41 1/2
4-GS-25	4-GW-25	2,304,000	8,400	13,440	2,880,000	4120	79 7/8	35	41 1/2
4-GS-28	4-GW-28	2,592,000	9,600	15,360	3,240,000	4625	81 1/2	39	41 1/2
4-GS-31	4-GW-31	2,880,000	10,800	17,280	3,600,000	5145	83	43	41 1/2
4-GS-33	4-GW-33	3,072,000	12,000	19,200	3,840,000	5480	79 7/8	31	41 1/2
4-GS-37	4-GW-37	3,456,000	12,800	20,480	4,320,000	6165	81 1/2	35	41 1/2
4-GS-41	4-GW-41	3,840,000	14,400	23,040	4,800,000	6850	83	39	41 1/2
			16,000	25,600				43	

xx To top of Draft Hood

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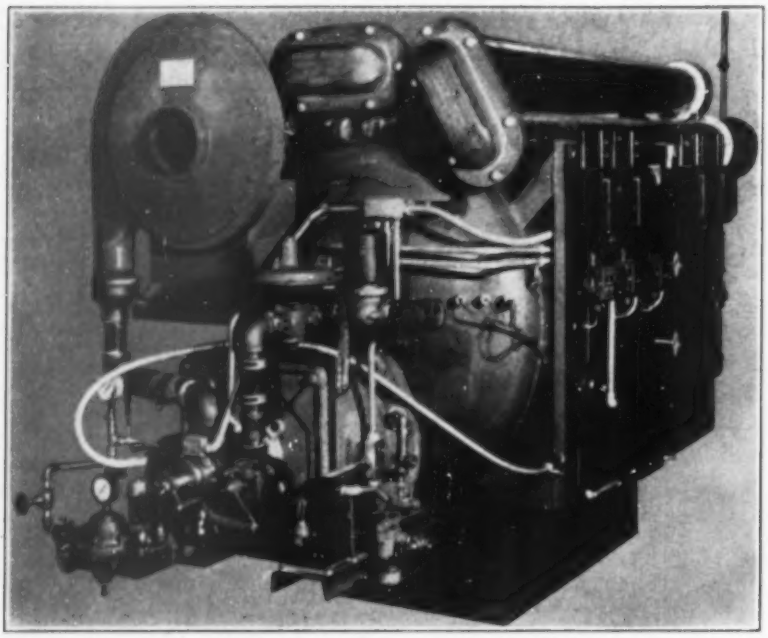


East Lansing, Mich.—Walker Process Equip. Co. Heat Exchanger

Gas Domes

In some early designs of digestion tanks, gas was withdrawn from a low, small dome, not much more than a manhole cover, in the roof not far above the sludge level. Experience soon indicated the need for larger and taller domes as under high rates of gas production there was at times sufficient disturbance of the liquid surface under the dome to carry moisture and particles of sludge and scum into the gas system. With domed roofs, the clearance between the liquid level and dome at the center of the tank is usually sufficient to minimize the requirements for a separate gas dome. For flat concrete roofs and floating covers, more elaborate gas domes should be provided.

Pressure and Vacuum Relief

Sludge digestion tanks, regardless of the type of roof, require provision for pressure and vacuum relief. Undue pressure within a tank may be created by sludge inlet pumps operating at a time when all outlets to the tank are closed or clogged. A vacuum may be created by the withdrawal of sludge at a greater rate than sludge is being admitted or sludge is being introduced.

Early designs of pressure and vacuum relief devices which relied on a "leg" of oil or water proved somewhat troublesome because of evaporation, freezing, "blowouts" or other difficulties.

Vapor Recovery Corp., Pacific Flush Tank Co. and others have developed valves which permit gas to escape from the tank if the pressure rises above a predetermined level or permits air to enter the tank if there is a tendency for vacuum to form. These valves are equipped with flame arresters to prevent a flame from flashing back into the tank when the vacuum release feature is operating.

Careful attention must be given to the design and operation of these valves. In one type of valve, some trouble has been experienced due to freezing of condensation in such a manner as to render the valve inoperative during severely cold weather. In another type of valve, the protection afforded depends upon the replacement of oil which may evaporate or be accidentally displaced.

Normally the floating cover is not subject to vacuum. However, in the event sludge is withdrawn while the cover is resting on the landing ledge, a sufficient vacuum can be created, unless a vacuum relief valve is provided, to cause serious structural damage to the cover.

General Comment

Particular attention should be given to the protection of structural steel members, cables, and other metal parts immersed in sludge digestion tanks from the corrosive effects of sewage sludge and possibly also from galvanic or electrolytic action. The difficulties encountered in the latter respect in a sludge digestion tank at the Terminal Island plant in Los Angeles have been described by Parkes[6].

Oil and grease lubricated bearings should not be used inside of digestion tanks. It is preferable to support rotating equipment from the structural roof using thrust bearings.

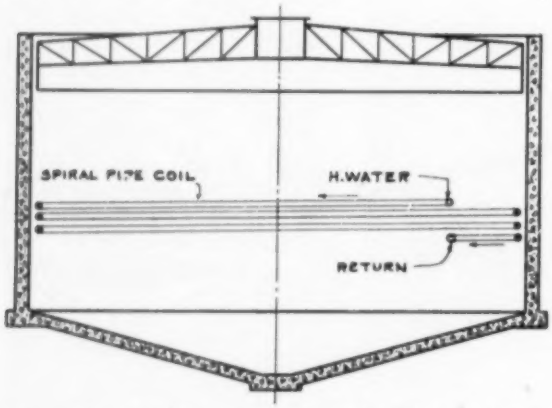
Piping should be designed of generous size. Maximum rates of gas production may be several times the average rate and should be provided for. Undersized sludge inlet and withdrawal piping has led to serious difficulties in a number of instances.

For the most part, the equipment installed within digestion tanks prior to World War II has not proven very satisfactory. The work of cleaning out a digestion tank and the making of repairs on mechanical equipment installed therein is laborious and distasteful to the operators. In many small plants with only one or two tanks, the withdrawal of one tank from operation to make repairs may necessitate by-passing a portion, if not all of the sewage flow, during the repair period.

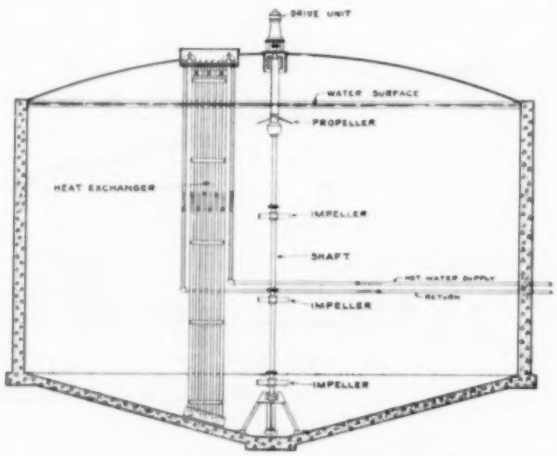
It is hoped that the newer developments will prove longer lasting and more effective than some of the earlier.

References

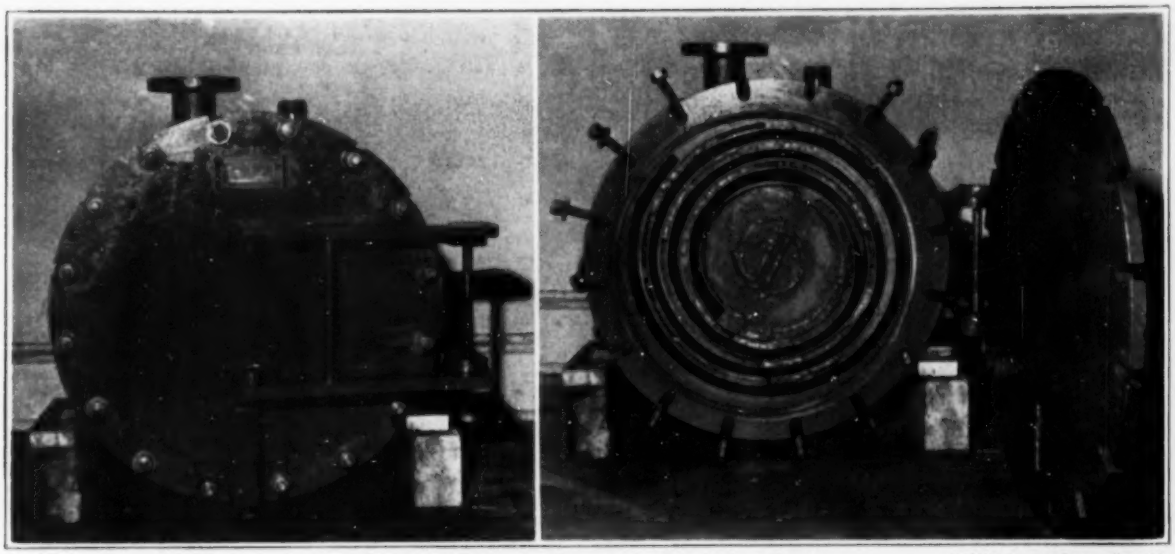
1 Heating Top Sludge, Henry W. Taylor, Public Works.
2 A New Method of Sludge Heating, C. E. Keefer, *Water and Sewage Works*, June, 1946.
3 New Heating System for Sludge Digestion, E. R. Schofield and M. B. Tark, *Water and Sewage Works*, May, 1948.
4 Sludge Digestion Temperature Control With Live Steam, A. M. Rawn, *Water Works and Sewerage*, July, 1942.
5 How to Control Scum in Digesters, F. L. Flood, ENR, June 26, 1947.
6 Corrosion of Sludge Digester Parts, G. A. Parkes, Water Sewage Reference Data, 1946, R 242.



Digestion tank with spiral pipe internal heating coil (after Wittwer)



Digestion tank with vertical bank heat exchanger (after Wittwer)



(With front door open) *Dorr Co. Counter Current Flow Type Spiral Heat Exchanger* *(With front door closed)*

5—Vacuum Filtration of Sludge

Mechanical dewatering by vacuum filtration of raw primary sludge has been employed at the Minneapolis-St. Paul sewage treatment plant since 1938. At this plant the sludge was conditioned prior to June, 1947 principally with ferric chloride and lime. As a five year average the dosages of ferric chloride was about 1.1 per cent and of lime about 3.1 per cent, both on the dry basis.

Following June, 1947, ferric sulfate was used in the place of ferric chloride when it was found impractical to obtain the latter chemical. During the early years of operation it became evident that the screens and woodwork were built up with excessive amounts of calcium carbonate which prevented the free passage of water into the interior piping system. It was learned that the periodic use of a hydrochloric acid bath containing an inhibitor resulted in the prevention of any major buildup of carbonate and at the same time extended the average life of filter cloth by 150 hr. to 200 hr.

In order to provide for washing of the filter cloth while the filter keeps on producing filter cake, the washwater pipe and spray nozzles were moved from their original location on the far side of the filter from the take-off plate, to a new location immediately behind and below the top edge of the take-off plate. The washing is done on the section of the drum between the take-off plate and the line of submergence in the filter pan. The spent washwater is collected in a trough which drains back to the settling tanks. Since November, 1947, the filters are washed at least once each hour for at least one revolution of the drum. Well water is used at a pressure of 50 to 70 psi.

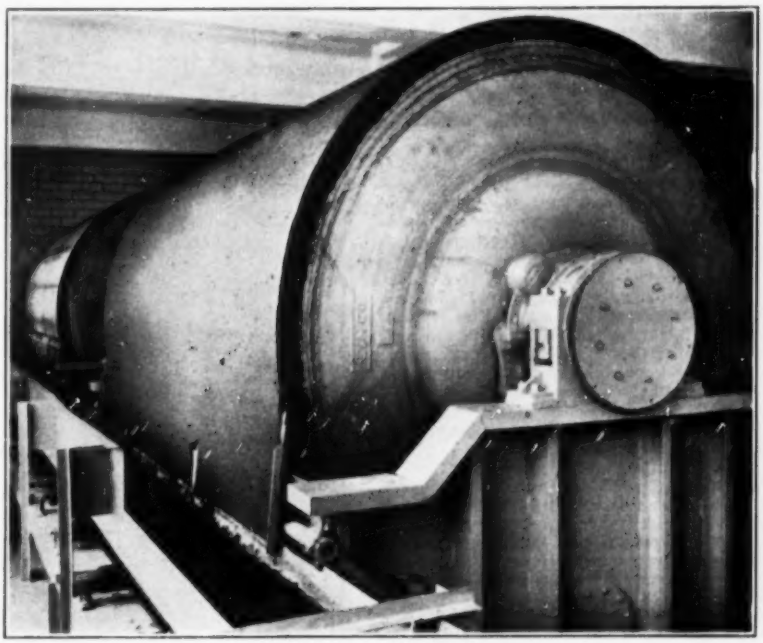
The operators state that the new method of washing has reduced filtration costs, increased the filter area available and produced a more even feed to the incinerators.

The ferric chloride or ferric sulfate and lime process used for conditioning raw sludge at Minneapolis-St. Paul is also used for conditioning other raw and digested sludges. Wherever lime is used, conditions such as encountered at the Minneapolis-St. Paul plant may be anticipated and the materials of construction should be designed to take care of normal operation with alkaline sludge and for occasional washing with inhibited hydrochloric acid.

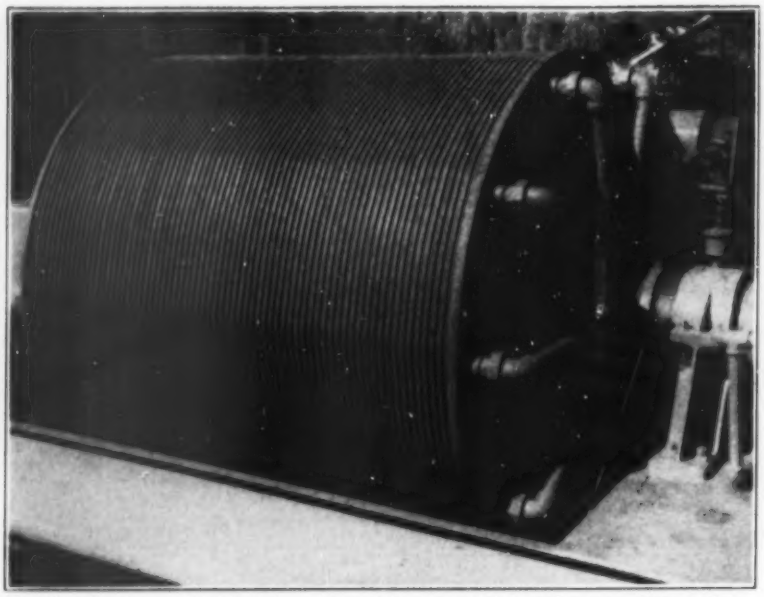
Acid Conditions

When sludge is conditioned with ferric chloride alone, as may be the case with waste activated sludge and with digested elutriated sludge, the materials of construction should be such as to resist corrosion from ferric chloride solution under acid conditions. In smaller plants or otherwise where the filters operate only a few hours each day, corrosion of filters constructed without due regard to the ferric chloride condition sometimes does not show up for several years. Where the filters operate practically continuously, however, corrosion of the filters of conventional construction may become troublesome in a matter of months.

For acid conditions it appears advisable to specify acid-resisting bronze screens, staples, division strips, etc. The pipe and fittings between the drum compartments and the trunnion conduits should be highly resistant to acid conditions. Heavy-walled chemical hose, with the individual lines supported to prevent the formation of moisture traps and to prevent movement when the drum is revolved, has been advanced as one solution to the problem. "Saran" tubing, manufactured by the Dow Chemical Co., has been used but there has been some



Norfolk, Va.—Eimco Filter



Komline-Sanderson Coiled Spring Filter with external piping of vacuum lines to drum

question of the permanency of the joints particularly inasmuch as there has been some plastic flow in pipelines made of "Saran." However, J. K. Adams[1] has reported that "Saran" piping in the vacuum filters at the Tenafly, New Jersey, sewage treatment plant has developed no leaks since the installation was made in 1944, the filtrate containing ferric chloride and having a pH of 4.0 to 5.0.

For the filters at the main Toronto plant, pipe and fittings of "Uscolite" as made by U.S. Rubber Company have been accepted for filtrate piping where sludge is to be conditioned with ferric chloride.

A newer model of vacuum filter has all vacuum piping connections outside the filter drum, thus greatly facilitating their repair or renewal.

Recent developments in the cord and coiled-spring-wound filters are promising. These filters do not require any filter cloth as the filter cake forms over the cord or spring coils and drops off as the filter media changes direction over an idler shaft off to one side of the filter drum.

Sludge Agitators

Agitators are sometimes supported from the trunnion shaft of the filter. It has been asserted that this method of support produces frictional resistance to the rotation of the drum when the agitator swings in a reverse direction, results eventually in a jerky operation in large drums and causes undue wear on the vari-drive mechanism. For this reason, some engineers recommend that the agitators be supported on bearings below the trunnion shaft, or on the ends of the filter tank. The frequency of agitator oscillations depends upon the size of the tank and the characteristics of the sludge. The driving mechanism should be of variable speed to accommodate possible requirements.

Cake Take-off Plate

The sludge cake take-off plate should be provided with a replaceable cutting edge. For acid conditioned sludge this cutting edge has been specified to be of 18 per cent chromium and 8 per cent nickel-steel alloy, at least 3/16 in. thick.

1 Sewage Works Journal, April, 1950, p. 562.

Cake Slicers and Distributors

Unless some provision is made for cutting it up, the cake from the filter may drop off in large masses which create somewhat of a problem on the belt conveyors customarily provided for carrying the cake to a point of disposal. A reasonable design is to provide replaceable steel pins about ¾ in. diameter threaded on one end for screwing into tapped holes on the cake apron. The pins should be spaced 8 to 12 inches on centers horizontally.

It is frequently helpful to provide a device for distributing the cake on the conveyor belt. This may be accomplished by mounting rotating cutting blades over the conveyor operated by a connection from a shaft on the conveyor. Experience at Hartford, Conn., and elsewhere has demonstrated that these cutters should revolve in the direction of travel of the belt. If they operate against the travel of the belt, there is a tendency for the cake to pile up in back of the cutters. The cutting blades are subject to considerable wear and should accordingly be designed to resist abrasion and for convenient replacement.

Auxiliary Equipment

Sludge Feed

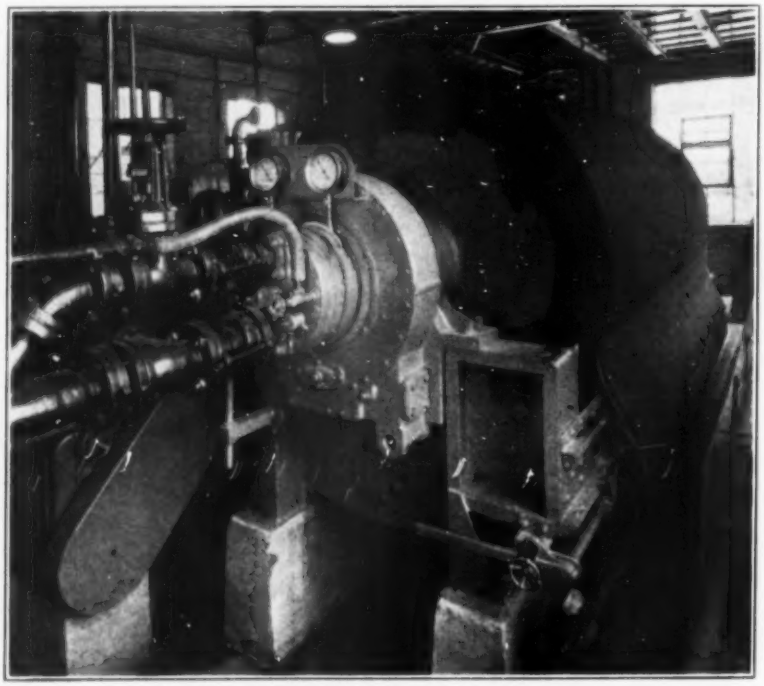
In the larger installations, sludge is commonly fed to the conditioning tank ahead of the filter by bucket elevator operating from a sludge well. The elevator may advantageously be driven through variable-speed transmissions under electrical control, designed so that the sludge will be elevated at the rate of filtration and the sludge load in the conditioning tank and filter tank will be maintained within approved limits. Floats of hard rubber or glass with tape or chain of acid-resisting materials have been used in float chambers at the sludge conditioning tanks, with electrical transmitting devices designed to operate in connection with the electrical controls at the variable-speed transmissions on the bucket drives.

Ferric Chloride System

The handling, storage, making up of solution and the application of ferric chloride to sludge for conditioning ahead of vacuum filters, create multiple problems because of the extremely corrosive nature of the material.

Ferric chloride in liquid form is commonly stored in rubber-lined tanks. Where large storage capacity is required as at the Hyperion Plant in Los Angeles, the liquid ferric chloride may be stored in reinforced concrete tanks with a protective covering such as "Amer-coat."

Ferric chloride pumps have not always proven satisfactory. Other solution feed equipment is available, if desired, or it is



Cleveland, Ohio (Westerly Plant)—Oliver Filter

FOUR YEARS EXPERIENCE WITH THE COIL SPRING SLUDGE FILTER

The pioneer installation of this type filter was made at Liberty, N. Y. in June 1949. This unit replaced a cloth type filter the operation of which was not satisfactory. Operation of the Coil Spring type filter continues to be completely satisfactory.

Since the pioneer installation approximately thirty other units have been shipped and fifteen are already in operation doing a superior job.

Operators are demanding and Engineers are specifying the Coil Spring type sludge filter on a practically unanimous basis for the following reasons:

1) When the plants are started there are no operational embarrassments for the Consulting Engineer.

2) With regard to operating reliability the Coil Spring type sludge filter is completely superior to the old-fashioned cloth type filter.

3) With regard to economy definite savings are made in the use of chemicals.

4) The following typical WARRANTY is made by the manufacturer:

(a) Filter performance shall be on the order of 10 lbs. dry solids per square foot of filter surface per hour; cake moisture content to be approximately 75%.

(b) Manufacturer shall maintain the filter media without charge for a period of 10 years after shipment if the filter unit is operated 40 hours per week, or its adjusted equivalent.

(c) The Coil Spring Filter is unconditionally guaranteed to work satisfactorily, and filter continuously, without clogging or blinding, provided that the sludge is conditioned to the following laboratory requirements: Utilizing a No. 2A Buechner funnel and working with 100 CC sample, the sludge is to dewater to a cake of 1/4 inch minimum thickness in 100 seconds.

5) With regard to materials of construction, stainless steel (type 304 or 316, depending upon the metallurgical requirements) is utilized in contrast to wooden staves and cloth blankets.

6) Any Municipality of 10,000 population or over is a definite application for sludge dewatering by a Coil Spring Filter.

Our modern factory that was erected in 1950 at Peapack, N.J., is already taxed to capacity and is now being tripled in size.

Inquires from Consulting Engineers in Sewage and Industrial Waste Treatment problems are invited.

KOMLINE-SANDERSON ENGINEERING CORPORATION

Manufacturers of Sewage and Industrial Waste Treatment Equipment

PEAPACK, NEW JERSEY

MORSE BOULGER

★ Mechanically-Stoked Incinerators

★ Rotating Hearth and Multiple Hearth Furnaces

★ Cell Type Incinerators

Order "Experienced" Units

Morse Boulger offers a line of Mechanically Stoked Incinerators and Hearth Furnaces to handle all types of municipal refuse, sewage sludges and industrial wastes. They are *engineered* for each job with a background of 60 years of experience in the field of incineration.

Included in the more recent Morse Boulger projects, either already in operation or currently being engineered or constructed are those on the accompanying list.*

Incineration is the *Modern* way to dispose of refuse, garbage, rubbish, sludges and wastes. It is practicable for *any* community regardless of size. It is suitable for many industrial wastes. If you have any such problem, our engineers will be glad to work out with you and your consulting engineers the best method and the details.

*NOTE: In addition to the communities now operating or installing Morse Boulger Mechanically Stoked Incinerators as listed, scores of cities and towns are disposing of their refuse in Morse Boulger Cell Type Incinerators.

Recent Morse Boulger Projects Mechanically Stoked Incinerators and Hearth Furnaces

City of Hartford, Conn.
Four (4) units of the stoker type; 600 tons/24 hrs. capacity on city refuse.
Engineers: Metcalf & Eddy, Boston.

Fort Worth, Texas
2 units for handling city refuse; approx. 250 tons.
Architect-Engineer: Wyatt C. Hedrick

City of Los Angeles
100 ton unit for city refuse; provision for second unit.
Engineers: Greelay & Hansen, Chicago

Mayaguez, Puerto Rico
60 ton unit for city refuse.

Gloucester City, N.J.
60 ton unit for garbage and rubbish, with upper rotary hearth for sewage sludge.
Engineers: Andrews & Gieseke, Philadelphia

The Atlantic Refining Co.
Point Breeze, Philadelphia
Large unit with waste heat recovery system for handling filter cake from waste water treating plant.

Esso Standard Oil Co.
Baltimore, Md.
For handling tank bottoms, liquid wastes, and general refinery refuse.

City of Saginaw, Mich.
Multiple hearth furnace for incineration of raw primary sewage sludge.
Engineers: Hubbell, Roth & Clark, Detroit

Merck & Co., Inc.
South Danville, Pa.
4 different units: two multiple hearth units, one for general rubbish and a waste solvent destructor.

Washington Suburban Sanitary Commission
Lyttonsville, Md.
75 ton unit for community garbage and rubbish.

Pomona, California
2 units totalling 225 tons for garbage and rubbish.
Engineers: Black & Veatch, Kansas City, Missouri

Lawrence, Mass.
2 units totaling 300 tons for garbage and rubbish.
Architects: Ashton, Huntress & Pratt
Engineers: Metcalf & Eddy

Gretna, Louisiana
2 units totalling 100 tons for garbage and rubbish.
Engineers: Alvin E. Hotard and Carl Schneider

Hempstead, N. Y.
4 units totalling 672 tons for garbage, rubbish, etc. Will be largest mechanically stoked municipal incinerator in the United States. Includes waste heat boilers, dust collectors, and mechanical ash removal.
Engineer: Henry W. Taylor

Merck & Co., Inc.
Rahway, N.J.
90 ton unit for general refuse.

HEAVY-DUTY INCINERATION

MORSE BOULGER DESTRUCTORS

MORSE BOULGER DESTRUCTOR CO.

205-W East 42nd Street, New York 17, N. Y.

Representatives in Principal Cities

sometimes possible to provide for raising the liquid ferric chloride by means of compressed air to small storage tanks at a high level from which the chemical can flow by gravity to the sludge conditioning tanks. Control of the rate of flow of the chemical can be accomplished by the use of ordinary pinchcocks.

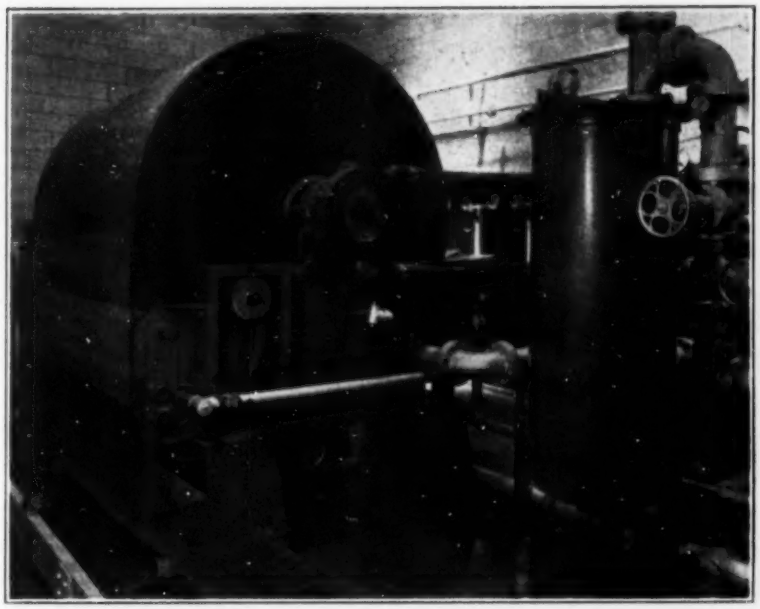
Ferric chloride solution lines may be of hard rubber, rubber-lined pipe, "Uscolite," "Saran," or other suitable acid-resisting materials depending upon the size of pipe and its situation. The valves should be of hard acid-resisting rubber. Plug valves may be of the "Durichlor-Nordstrom" lubricated type as made by the Duriron Co.

Automatic pH Control

It is believed that automatic pH control of ferric chloride addition in connection with conditioning of digested elutriated sludges in the larger plants should result in economical use of ferric chloride under suitable conditions and proper regulation.

Mixers and Conditioning Tanks

It has been demonstrated that the design of mixing tanks for sludge and conditioning chemicals and the point and method of application of chemicals to the sludge in the mixing tank are of considerable importance for economical operation and for obtaining the optimum results at the filters. Elutriated sludge floc forms very rapidly after the addition of the chemical and the floc, once formed, should receive a minimum of disturbance and should be discharged to the filter tank as soon thereafter as is practical.



New Brunswick, N.J.—FEinc. Filter, string discharge

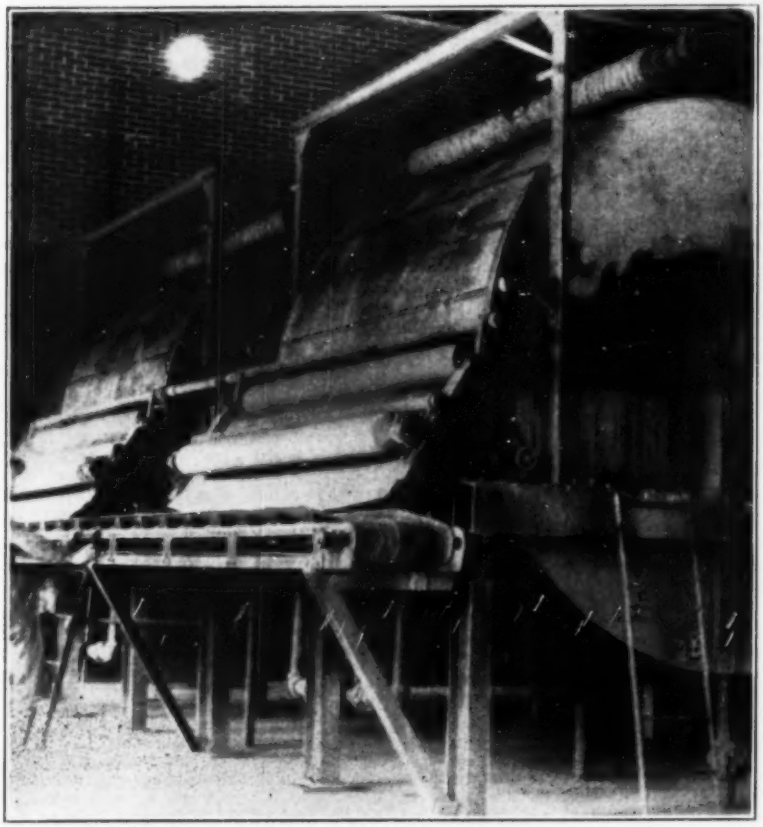
Vacuum Pumps

Wet vacuum pumps such as the Nash Hytor Rotary are used on the smaller filter installations. Vacuum pumps such as Ingersoll-Rand, or Worthington, single-stage, reciprocal dry vacuum pump, are used on the larger installations.

Each pump discharge should be provided with a suitable Burgess or Maxim silencer, of sufficient capacity to effectively silence the exhaust.

Vacuum receiver should be lined with rubber or coated with fibrated asphalt emulsion.

Moisture traps should be provided between the vacuum receivers and the dry vacuum pumps, designed to remove the greatest percent possible of the moisture contained in the air in the vacuum line after it has passed through the vacuum receiver.



York Township, Ontario—Wright String Discharge Filters

Package Units

Several of the manufacturers now offer package units which include the vacuum filter, vacuum pump, blower, filtrate pump, chemical feed equipment and conditioning tank. For filter units up to a size of at least 100 sq. ft., the package units appear to be both practical and economical. The manufacturer in the case of the package units usually assumes responsibility for all of the equipment included therewith. He purchases the appurtenant items of equipment and assembles them in his shop. The assembly therefore requires a minimum of space and minimizes installation problems. This arrangement may be advantageous when the owner is in need of maintenance, repair, and replacement service.

General Acid-Resisting Construction

Equipment which handles ferric chloride conditioned sludge should be of acid-resisting construction. Specifications quite commonly provide for a protective rubber coating $\frac{1}{16}$-in. thick or more, or a coating of fibrated asphalt at least $\frac{1}{8}$ in. thick. The protective coating is customarily applied to the inside of conditioning and mixing tanks, the inside of the filter tank, both ends of the drumheads, the overflow chamber, the agitator blades and arms, the mixing shaft and other parts of the equipment not otherwise suitably protected or of acid-resisting materials.

6—Multiple Hearth Incinerators

A considerable number of multiple hearth sludge incinerators have been installed in the United States, the larger installations being at Detroit, Minneapolis-St. Paul, Cleveland, and Columbus. Representative smaller units include those at New Britain and New Haven, Conn.; Wyandotte, Mich.; Ashland, Piqua, and Barberton, Ohio; and Elmira, N.Y. All of these units were manufactured by the Nichols Engineering & Research Corp.

The Martin multi-zone furnace, presently manufactured by Morse Boulger Destructor Co., has been installed for sludge incineration at Raritan and Rutherford, N.J.; Lansing, Mich., and Wisconsin Rapids, Wis. At present only the Lansing unit is in operation and that for sludge drying. Similar units have been installed for incineration of screenings at Niagara Falls, N.Y., and Milwaukee, Wis.

Design Features

The multiple hearth furnace consists of a cylindrical shell mounted on columns supporting hearths one above the other, the shell lined with a wall of insulation and firebrick.[1] A vertical air-cooled central shaft revolves and turns horizontal arms above each hearth. Teeth attached to these arms continually stoke or rabble the sludge so that it moves progressively downward through the furnace. When designed as an incinerator, hot gases produced by the burning of volatile matter in the sludge, or from supplementary fuel such as oil or gas, pass upwards through the furnace in counter current to the sludge.

Special provisions are advisable if the multiple hearth unit is to provide for both incineration and drying. In addition to the method above described while operating as an incinerator, provision should be made for burning oil or gas over the upper hearths and drawing the hot gases down through the furnace parallel with the travel of the sludge.

The Nichols Multiple Hearth Unit at Dayton, Ohio, has been operated in this manner as a drier since 1939. Digested sludge partially dewatered on sludge-drying beds is further dried to below 8 per cent moisture for sale as fertilizer. Sludge gas burns on the upper hearths and supplies the heat for drying.

At the Toronto Ashbridge's Bay plant two multiple hearth units designed to either incinerate or dry sludge cake, and with a unit capacity to evaporate 12,000 lb. of moisture per hour, have been contracted for. Provision will be made in connection with these units to mix a portion of the dried sludge removed from the bottom hearth with the filter cake before the latter is admitted to the top hearth.

In the following text the writer has summarized operating experiences with multiple hearth units at a number of sewage treatment plants, based upon personal observations, published reports, and comments by the plant operator. The observations presented should not be construed as criticism of designers, manufacturers, or operators. It is the intent to record difficulties which have been experienced, measures taken to improve conditions, and to record operating results so that others facing similar problems may profit thereby.

Detroit

The largest installation of multiple hearth sludge incinerators is at the Detroit sewage treatment plant. There are four units each 22 ft. 9 in. outside diameter with 12 hearths as initially installed and a rated capacity of 330 tons of sludge cake per day. The initial plant included preheaters designed to use the hot gases leaving the incinerator to preheat the air used for combustion. In actual operation, the heat value of the volatiles in the raw sludge under normal conditions of operation have been more than sufficient to support combustion. The operation of the preheaters was not necessary and in fact not desirable.

Operating difficulties with the incinerators at this plant disclosed the necessity for a number of changes in methods, equipment, and appurtenances in order to obtain best results.

In the operation of the Detroit incinerators, it has been found that excessive temperatures caused damage to the equipment and low temperatures caused excessive smoke in which case the burning of large quantities of fuel oil would be required to correct the situation. An important operating feature has been the control of the feed to prevent sudden changes, particularly in the amount of grit and screenings. The problem created by the screenings disposal was in large measure solved by grinding and returning them to the sewage flow. Until recently, it was not practical to dispose of all the grit removed at the plant by incineration. However, changes now being made which include grit storage and feed by means of screw conveyors at a uniform rate from the storage hopper to the conveyor belts discharging to the incinerators should make it practical to incinerate all of the grit with a minimum of operational difficulty.

The initial reciprocating plate feeder on several of the individual incinerator units has been replaced with a variable speed ribbon conveyor and storage bin. This change is reported to have resulted in the elimination of smoke leaks, better and more uniform distribution, and less violent temperature changes.

Some rabble arms are of 12 percent chromium and 12 percent nickel, others are of Nercaloy. The rabble arms of 25 percent chromium and 12 percent nickel must be insulated in the combustion zone in order that they may have reasonable life. Replacement of rabble arms has been greatly reduced since temperatures have been controlled at under 1,600 deg. F. for most of the time. Temperatures are controlled by allowing cool air to enter the furnaces through the hearth doors and by regulation of butterfly dampers in the enlarged section of the ducts ahead of the stacks.

Weightmeter counters have been installed on the control board and also in the filter room to permit closer observation and control of the feed rates.

The linings in the steel stacks through which the vapors from the incinerators are discharged, as initially constructed, were not suitable for the temperatures encountered. Recently corrosion, reportedly caused by acids present in the flu gases, has been a serious problem at the inner faces of incinerator shells, breechings and stacks.

Improvements to incinerator No. 4 have increased its rated capacity to 14 or 14½ tons of sludge cake per hour. The normal working capacity for average monthly production is 12 to 13 tons per hour. This remodeled unit has 11 hearths and enlarged drop holes in the drying and combustion zones. The most important feature improvement to this unit was the additional flue capacity. A large number of lance holes were provided on out hearths to facilitate cleaning and to provide an abundance of fresh air. The latter is reported to be of importance to minimize slagging.

During 1949 the incinerators burned all of the 194,797 tons of filter cake produced at the plant, all of the 1,132 tons of scum removed from sedimentation tanks, and 99.97 percent of the 15,127 tons of grit removed from the grit chambers.

How unit unloadings on multiple hearth incinerators may be best expressed is still a question. The interior diameter, number of hearths, net hearth area, volume for combustion, moisture evaporated, solids destroyed by incineration and ash handled, are important factors. Assuming adequate volume is provided for combustion per unit of hearth area, a unit of loading in terms of pounds of moisture evaporated and solids burned per square foot of net effective hearth area may have significance for purposes of making comparisons of performance between units at various plants. A test load on Detroit incinerator No. 4 resulted in the incineration of 14.31 tons of sludge cake per hour. This cake contained 36.41 percent solids and 52.08 percent volatiles dry basis. The moisture evaporated was about 9.1 tons per hour and the solids incinerated were about 2.7 tons per hour. The net hearth area of this incinerator is 2,500 sq. ft. and the load during this test per square foot of net area per hour was equivalent to 7.28 lb. of water evaporated and 2.16 lb. of solids incinerated, making a total of 9.44 lb. of water and volatiles. Including ash, the rate was 10.5 lb. per sq. ft. per hr.

The ash sluicing pumps have been taken out of a pit and installed at floor level to facilitate their servicing and maintenance.

As first constructed, the Detroit incinerator building was poorly ventilated. In the warmer months, the temperature in the upper operating gallery and under the roof was said to be over 130° F. and there was considerable odor of scorched sludge. Subsequently, four ventilating exhaust fans each of 40,000 cfm. capacity were installed on the roof of the incinerator building to exhaust smoke and gases and to improve conditions within the building.

1 Recent refractory hearths have been cast in place in certain locations within the incinerator units. There are indications that this type of hearth is more satisfactory for some hearths than those made of individual firebrick blocks.

Minneapolis-St. Paul

There are three multiple hearth incinerators at this plant, each 22 ft. 3 in. outside diameter and with eight hearths. Each unit as provided had a rated capacity of 60 tons of dry solids per 24 hr., based on 65 percent moisture in the filter cake and 60 percent combustible matter in the dry solids. A fourth similar unit is under construction. Grit and scum are not burned in the incinerators.

The design assumed that supplementary fuel would be required for incineration of the sludge and that temperatures could be controlled by regulation of the feed of the fuel. However, it was found under practically all conditions of operation an excess of heat existed and no supplementary fuel was required.

Instead of an anticipated maximum temperature of 1,600 deg. F. actual temperatures exceeded 2,200 deg. F.

The preheaters were removed from service with resultant reduction in power and maintenance costs.

It was found that if the feed rate was kept below 1.4 tons of combustibles per incinerator per hour excessive temperatures were practically eliminated. A chart was prepared showing safe rate of feed of filter cake to an incinerator unit for various percentages of solids and combustibles. The operators have found this chart very useful as a guide to operation.

The net hearth area is 2,084 sq. ft. per unit. The nominal capacity of each incinerator unit is equivalent to about 5.4 lb. per hour of moisture evaporated and solids consumed per square foot of net hearth area. On occasion, the units have been reported to satisfactorily handle an overload of approximately 33 percent. On the annual average the units operate at between 85 and 95 percent of the time.

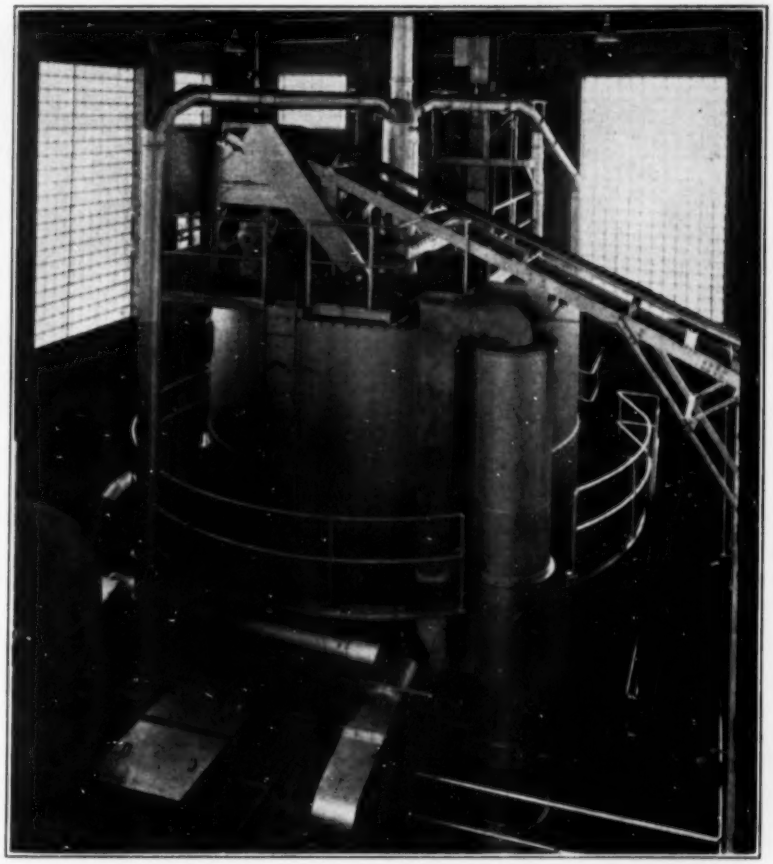
Based on present rated capacity of 1.4 tons of combustibles per incinerator hour, the three incinerators for the past 2 years have averaged approximately 72 percent of capacity. At numerous times during the year individual furnaces may be operated at near capacity for several days at a time.

Maximum temperatures of incinerators are kept below 1,600 deg. F. by operation of an induced-draft fan with variable-speed drive. The fan follows a duct in which water is added as necessary to keep the gas temperature at the fan below 700 deg. F. and protect the fan from damage by overheating. The speed of the fan is controlled from the main operating panel where the hearth temperatures are also recorded.

Ventilation in the incinerator building has been somewhat of a problem. Fixed glass blocks have been replaced by ventilating sash across one end of the building to supplement the three large ventilators placed in the roof. A wall fan has been added to cool a "dead" area in one corner of the incinerator. A similar fan is to be installed over the fourth incinerator now being built.

Cleveland-Southerly Plant

There are four multiple-hearth furnaces at this plant, each unit 18 ft. 9 in. outside diameter with eight hearths. The specified capacity per unit was 100 tons of digested sludge filter cake at 75 percent moisture content per 24-hr. day. In 1940, it was reported that these units could be operated at the average rate of 60 tons per incinerator day. In 1941, the capacity was reported to have been reduced to 50 tons per incinerator day. The inability to obtain design capacity was said to be primarily due to rapid accumulations of fly ash in the preheater passages. It was impossible to clean these passages with the preheaters in operation. On this account, the incinerators suffered from lack of adequate draft and a reduction in capacity.



Lansing, Mich.—Martin Multiple Hearth Incinerator

In 1942, three of the eight preheaters were eliminated, the other five cleaned and repaired, the combustion air ducts were enlarged, a bypass provided around the preheater units, gas boosters were added, and the number of gas burners was increased. Subsequently, the preheaters have been used infrequently. As a result of these changes, the unit incinerator capacity was increased to 80 tons of cake per day in 1943. The rate of operation with cake containing 31.9 percent solids of which 38 percent were volatiles was equivalent to 3.43 lb. of moisture evaporated, 0.60 lb. of volatiles consumed, and 4.03 lb. of moisture and volatiles per square foot net hearth area per hour. The average rate of operation in 1945 was 81.6 tons of cake per day per unit, the cake containing 28.4 percent solids of which 44.3 percent were volatile. The unit load in pounds of moisture evaporated and pounds of volatiles consumed was substantially the same as for the 1943 rated capacity as given above.

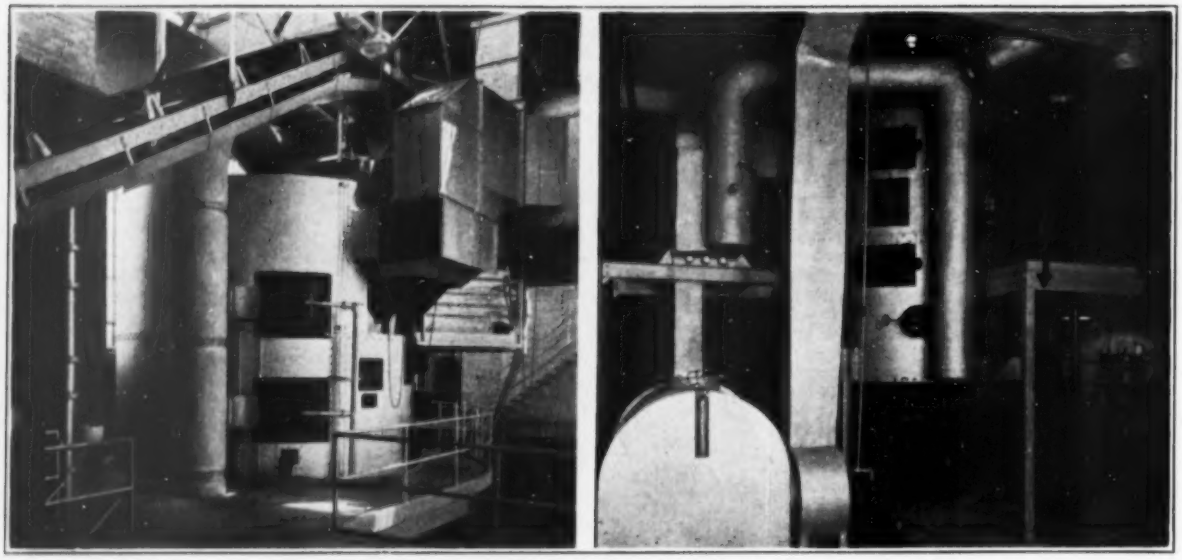
The multiple-hearth units at this plant were designed and initially operated on a somewhat different principle than those handling raw sludge at Detroit and Minneapolis-St. Paul. The top four hearths were drying hearths and are separate from the lower hearths. The hot gases from the combustion hearth beneath the drying hearth did not pass up through the upper hearth, instead they passed through the preheaters and thence up the stack. The gases from the drying hearth at a temperature of 500 deg. F. were passed through the preheaters where it was intended that they be raised to a deodorizing temperature of 1,200 deg. F. and then cooled down to about 500 deg. F. before being discharged to the stack.*

The preheaters are of the steel plate envelope type. As originally installed they were not suitable for the service. Dust and fly ash accumulated in the passages, greatly reducing their capacity and seriously limiting the output of the incinerators. The preheater units could not be cleaned without shutting down the incinerators and the cleaning operations were difficult to perform. In the operating reports, it is stated that the steel envelopes warped even though temperatures were kept within permissible limits. A portion of the preheaters were reported to have burned out during 1941.

Occasional operating difficulties reported include the slowdown or partial interruptions by brick falling out of the hearth, by clinkering of the ash, and by burning out of the bag filters on the ash line.

In 1944 it was reported that considerable trouble was experienced with the warping of the rabble arms and teeth especially on hearths 5 and 6. The pyrocast arms which were used during that period were insulated with Kastset using nichrome wire as reinforcement to prevent warping. One ring of the refractory was removed from hearth 5. Eventually rabble arms on the lower or combustion hearths containing 25 percent

*In 1942, after the incinerators were revamped, the method of burning sludge was on the same principle as at Detroit and Minneapolis-St. Paul.



Two examples of small Nichols Multiple Hearth Incinerators
Wyandotte, Mich. (on left) and Middletown, Conn. (on right)

chrome and 12 percent nickel were found to be satisfactory.

Theoretically all the vapors and gases discharged from the stack have passed through deodorizing temperatures. The stack extends only a few feet above the roof line and the wind currents from the bluff above the plant drive the vapors down to ground level. Observers have reported that at times a decided odor of scorched sludge has been detected in the vapors from the stack.

Ventilation in the incinerator building during the summer months has been reported as unsatisfactory. During this period, there is a tendency for the operators to spend as much time as possible out of doors.

Columbus, Ohio

The multiple-hearth incinerator at Columbus has an outside diameter of 16 ft. 9 in. and has six hearths. It was designed to incinerate 80 tons per day of digested sludge containing 75 percent moisture and 12½ percent combustible matter wet basis. It is reported to have a capacity to burn 50 tons per day of digested sludge filter cake at 75 percent moisture and 50 percent volatiles dry basis. The net hearth area is 845 sq. ft. The reported unit capacity is equivalent to 3.70 lb. of moisture evaporated, 0.56 lb. of solids consumed, and 4.26 lb. of moisture and volatiles per square foot of net hearth area per hour. For 1950 the average feed rate was 1.7 tons per hour of cake containing 28.8 percent solids of which 38.4 percent were volatiles. This is equivalent to 2.87 lb. moisture evaporated, 0.43 lb. of solids consumed, and 3.52 lb. of moisture and volatiles per sq. ft. of net hearth area per hour.

Operating reports indicate that it is necessary to shut down this unit for 15 percent of the time in order to make repairs such as renewing rabble teeth and replacement of rabble arms.

An air preheater of the sectional plate type was originally installed with 2,484 sq. ft. of heating surface. All of the equipment within the preheater was removed after the incinerator was placed in operation and the unit lined with firebrick so as to serve as a flue. The preheater became so caked up that it limited the passage of hot gases and greatly restricted the incinerator capacity.

As originally installed, all of the rabble teeth on the arms over the upper hearth were directed so as to move the sludge toward the outer edge. Two rabble teeth on each arm have been reversed so as to hold back some of the sludge cake and increase the drying time. Observations have shown an unusually deep accumulation of sludge cake, well broken up and well mixed as a result of this minor change. Ordinarily the top two hearths in this unit are drying hearths. The third and fourth hearths are combustion hearths and the fifth and sixth are for completion of combustion and cooling off of the ash.

Some of the heat from the exhaust gases is reclaimed under low-pressure steam boilers and used for heating the plant buildings and the sludge digestion tanks.

As in a number of other plants employing sluicing, ash handling has given considerable trouble at the Columbus plant. Lime is used for sludge conditioning and has accumulated as $CaCO_3$ in the ash hopper and in the ash lines to an extent requiring considerable work for removal. Clinkers have accumulated in the ash tanks and have been difficult to remove. This experience points to the desirability of having a quick-opening gate between the lower hearth and the ash hopper so that ash can be stored on the lower hearth while the work of removing clinkers and lime encrustations in the ash tank is carried on. Also clinkers find their way into the slurry pump, causing serious cutting of the impeller and rubber lining.

Difficulties with calcification in the wet ash discharge lines have led at Columbus to serious consideration of discharging the ash in a dry condition. The operators are of the opinion that if wet ash from lime conditioning sludge must be pumped, ample provision should be provided for removal of encrustation and the pipeline should be readily accessible for cleaning operations.

The incinerator chimney at Columbus includes a lined steel stack manufactured by Prat-Daniel and designed for a head induced by a cold air fan which acts as an injector. Cold air is forced into the stack near the restricted section so as to create a draft of up to 2 in. in the gases from the incinerator and boilers. The cold air, induced-draft fan has a variable speed drive and the draft can be governed within desirable limits. This arrangement eliminates a hot air induced-draft fan and provides an excellent means for regulation of incinerator operation.

Ashland, Ohio

The results of incineration of liquid sludge at Ashland, Ohio in a multiple-hearth unit have been reported by Laboon.* This unit is 9 ft. 3 in. outside diameter. As initially built it had four hearths. It was found advisable to add two hearths in order to incinerate concentrated liquid sludge in this unit.

The results of 6 days of tests made during September and November, 1947 have been given by Laboon. The unit was operated 140.33 hours, evaporated 146,499 lb. of moisture, consumed 18,473 lb. of volatiles, and passed 6,130 lb. of ash during the period. The unit rate of operation was about 5.39 lb. of moisture evaporated and 0.68 lb. of volatiles consumed per square foot net hearth area per hour.

Summary

On the basis of operating experience some of the features of design, construction, and operation of multiple-hearth furnaces to be used for drying and incinerating sewage sludge requiring particular care follow:

1. There should be ample capacity to discharge the products of drying and combustion. The drop holes should be of such size as to pass the hot gases upward and the sludge downward without clogging and undue loss of head.

2. Preheaters are not necessary for economical incineration of raw sludge cake.

3. Preheaters if provided should be a type which can be cleaned with facility. An ample bypass should be provided for each preheater unit so that it may be cleaned while the incinerator unit remains in opera-

*John F. Laboon, Sewage Works Engineering, 1949, p. 64.

tion. Preheaters of the closely spaced plate type are not satisfactory for this type of service.

4. Adequate means should be provided to permit an even rate of feed to the incinerator unit, particularly of moisture and combustibles. The rate of feeding relatively low volatile grit and relatively high volatile scum should be subject to fairly close control.

5. The rabble arms and teeth in the combustion hearths should be of heat resisting alloys. The central shaft at combustion hearths should be suitably insulated. A liberal allowance should be made as to the extent to which combustion may proceed above and below the theoretical average combustion zone.

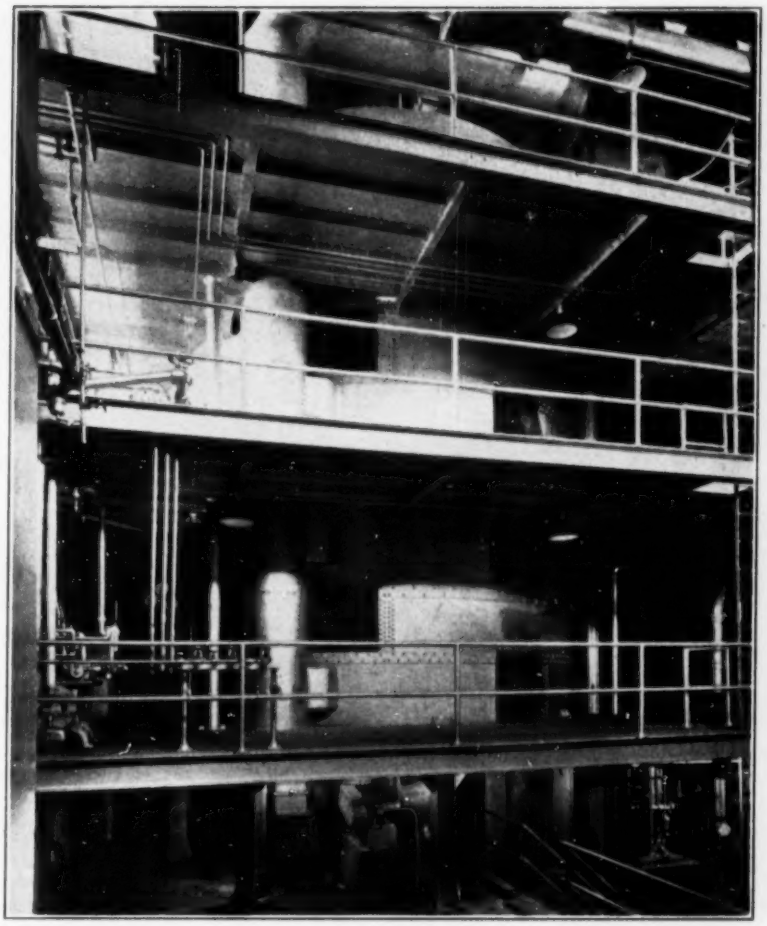
6. Consideration should be given to the protection of the incinerator stack against high temperature gases under certain conditions and against the corrosive action of acid and moisture under certain other conditions.

7. The ash system should be designed for ready access. A shutoff gate is desirable between the lower hearth and the ash system so that the latter may be worked on while the incinerator unit remains in operation. Ash slurry discharge lines should be designed so that stoppages may be cleaned or encrustations removed. Duplicate ash discharge lines may be required in order to make shut down unnecessary.

8. Adequate ventilation should be provided in sludge drying and incinerator buildings so that working conditions are not too uncomfortable.

Acknowledgement

Acknowledgement is gratefully made for data supplied by Fred H. Burley, Engineer of Sewage Treatment at Detroit; Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul plant; George E. Flower, Commissioner of Sewage Disposal at Cleveland; James H. Blodgett, Superintendent of Sewage Treatment Works at Columbus; and Robert W. Rowen, Vice President of Nichols Engineering & Research Corporation.



Minneapolis-St. Paul Sanitary District Incinerator

7—Flash Drying and Incineration

The following article differs from others in this series in that it deals only with the product of one manufacturer although the preceding article covered for the most part only the multiple hearth sludge drying and incinerating equipment as manufactured by Nichols Engineering & Research Corp. As heretofore in these articles it is the intent to record operating experiences and measures taken to improve the equipment and its maintenance so that others facing similar problems may profit thereby.

History

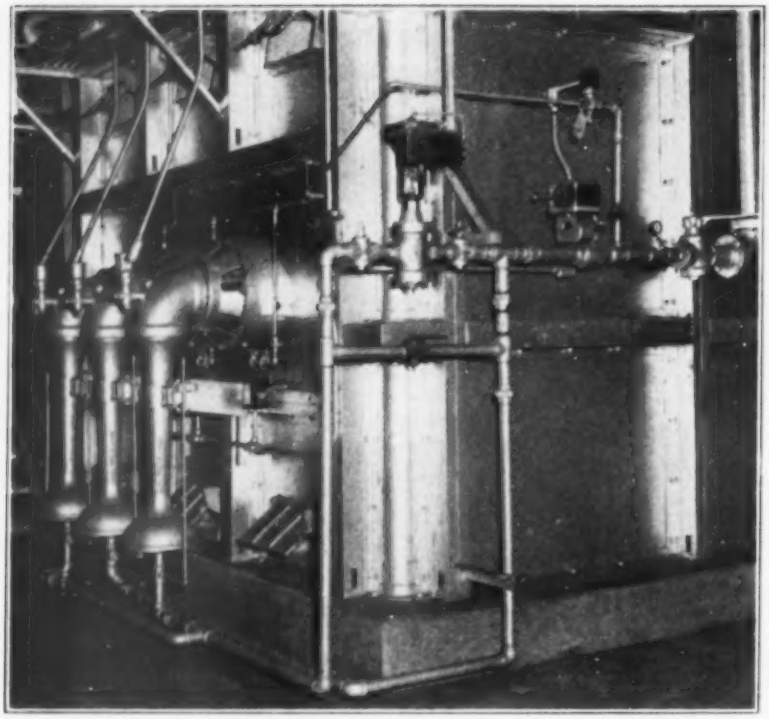
The C-E Raymond system of flash drying and/or incineration was first undertaken on a large scale at the West Side Plant of the Chicago Sanitary District in 1935. Subsequently, numerous installations have been made including other plants at Chicago and at Neenah-Menasha, Wis. (1937); Buffalo, N.Y. (1938); Springfield, Mass. (1940); Cuyahoga Falls, Ohio (1940); Duluth, Minn. (1941); Manitowoc, Wis. (1941); San Diego, Calif. (1943); Battle Creek, Mich. (1944); Sheboygan, Wis. (1946); Houston, Texas (1950); and Los Angeles, Calif. (1950). Large installations not yet under operation include those at Baltimore, Md.; San Francisco, Calif.; Waterbury, Conn.; Schenectady, N.Y.; Bethlehem, Penn.; and Washington, D.C.

In the C-E Raymond system, filter cake is mechanically mixed with a portion of dry material in a mixer of the pugmill type, and then violently agitated in the presence of hot gases in a cage mill. The mixture discharges into a cyclone collector. The sludge at about 10 percent moisture separates in the cyclone from the hot vapors and gases. A portion of the dry material is returned to the process and the remainder may be drawn off and disposed of in the dry form or burned in the furnace which supplies the hot gases for the cage mill.

This type of unit is also used for fertilizer production or for incineration in connection with standard garbage and refuse incinerators. The units at Watervliet, N.Y.; and Stamford, Conn., are of this type.

Buffalo

At Buffalo, N.Y., there are three flash drying units each designed to evaporate 5,833 lb. of moisture per hour with associated furnaces for incineration of the dried



Houston, Texas—Two units for activated sludge

sludge. Soon after these units were started in operation, it was found that the sewage sludge contained a substantial proportion of sand which proved to be very abrasive. Points of wear included mixers, the cage mills, the separating cyclones and in the fuel pipeline which transported the dried sludge from the flash drying system to the burners. Operating experiences have been described in the annual reports and by Velzy, Johnson and Symons.†

Drying towers were provided where hot gases from the furnaces are mixed with sludge before passing to the cage mill. These were lined initially with stainless steel plates which became distorted after a period of operation. Replacement of the buckled liners with a ceramic material poured in a wooden form proved to be a satisfactory solution to this problem.

The dry sludge cyclones were originally equipped with mild steel replaceable liners. It developed at Buffalo and elsewhere that this method of lining was uneconomical. The manufacturers made an intensive study of the problem and arrived at the conclusion that a gunite lining, consisting of trap rock and lumnite cement, was a satisfactory and economical protection for the interior of the sludge cyclones. Several of the cyclones at Buffalo have been lined with a ceramic known as "packing house floor tile," or with quarry tile.

The solution for the wear on the paddles in the mixers appears to be a paddle with easily replaceable abrasion resisting tip.

Changes made to one cage mill at Buffalo illustrates current standard practice. In order to provide for more economical maintenance, the housing was built to allow for rapid dismantling and provision made to pull the agitator mill out on rails for inspection or adjustment. The need for this was demonstrated as the rods on the rotor and stator were subjected to severe abrasion. As first rebuilt, the rods in the cage mill were protected with high manganese steel but these were expensive and wore out rapidly. A second development using a double, extra heavy, 1¼-in. steel pipe sleeve over a ¾-in. gave more economical results. With further experience, it is indicated that the most economical design is to supply 0.40 carbon steel bars and to build them up with stellite or other hard facing material as wear occurs.

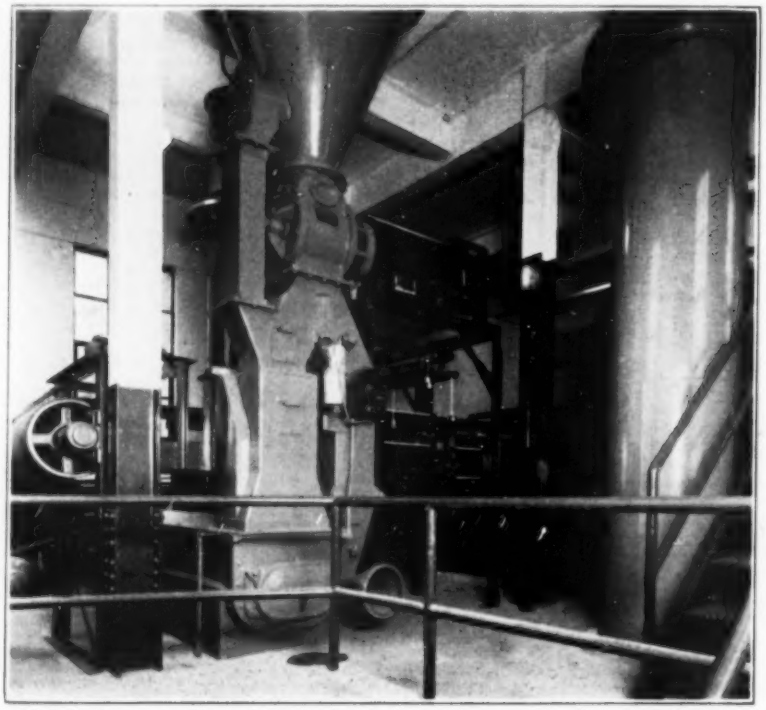
The fuel pipelines initially installed at Buffalo have been removed and have not been used subsequently at other plants. The standard type of sludge feeder now consists of a duct from the drying cyclone to a screw conveyor which feeds the sludge burner.

The induced draft fans as originally installed were on the dirty air side of the ash cyclone. The fans wore rapidly and repairs and replacements were difficult to make. When these fans were moved to the clean air side of the ash cyclones, the wear due to abrasion by sand in the ash was largely eliminated.

The initial installation of pneumatic equipment for ash removal included a cyclone bag filter and vacuum pump. With the temperature of the ash at 1,100-1,113 deg. F., the bags in the filter burned out and the vacuum pump became plugged with ash, a problem solved by installing a second cyclone in place of the bag filter and a steam ejector in place of the vacuum pump.

Springfield, Mass.

The unit at Springfield has a rated capacity of 10.5 tons per day dry weight of digested sludge solids per 24 hr. when drying sludge cake containing 67.5 per cent moisture with 50 per cent volatile dry basis. During the 10 years 1941-1950, inclusive, the unit was operated on the average of 1,411 hr. per year or approximately 5.6 hr. per work day for a 5-day week, while handling the total sludge production. The average moisture evaporated was approximately 750 lb. per hour of operation. The auxiliary fuel in the form of sludge gas used for burning the sludge amounted to about 650 cu.ft. per 1,000 lb. of moisture



Stamford, Conn.—Flash drying system in connection with garbage and refuse incineration

†Sewage Works Journal, September 1940.

Los Angeles, Calif.—Hyperion Plant has four units for handling activated sludge

evaporated. This is reported for conditions in which there is an abundance of sludge gas at the plant and where it is not necessary to take particular care in the conservation of fuel at the incinerator.

During the years 1943 and 1944, the sludge was dried for fertilizer but in other years the market was not favorable enough to warrant drying operations and expense.

As in the case with Buffalo, the drying cyclones were initially lined with steel plates. They have subsequently been relined with a mortar of lumnite cement and trap rock. The life of the paddles in the sludge mixers has been extended by adding a facing of abrasion resisting materials by means of electric welding.

John P. McDonald, sewage treatment plant engineer, at Springfield, reports complete satisfaction with the installation after 10 years of operation. He states one of the advantages of this type of equipment is the facility with which it can be started up without undue delay in preheating or without burning fuel during nightly or weekend shut-downs. The practice of burning during the day shift only and with no heating during the standby period has not resulted in evident damage to the furnaces.

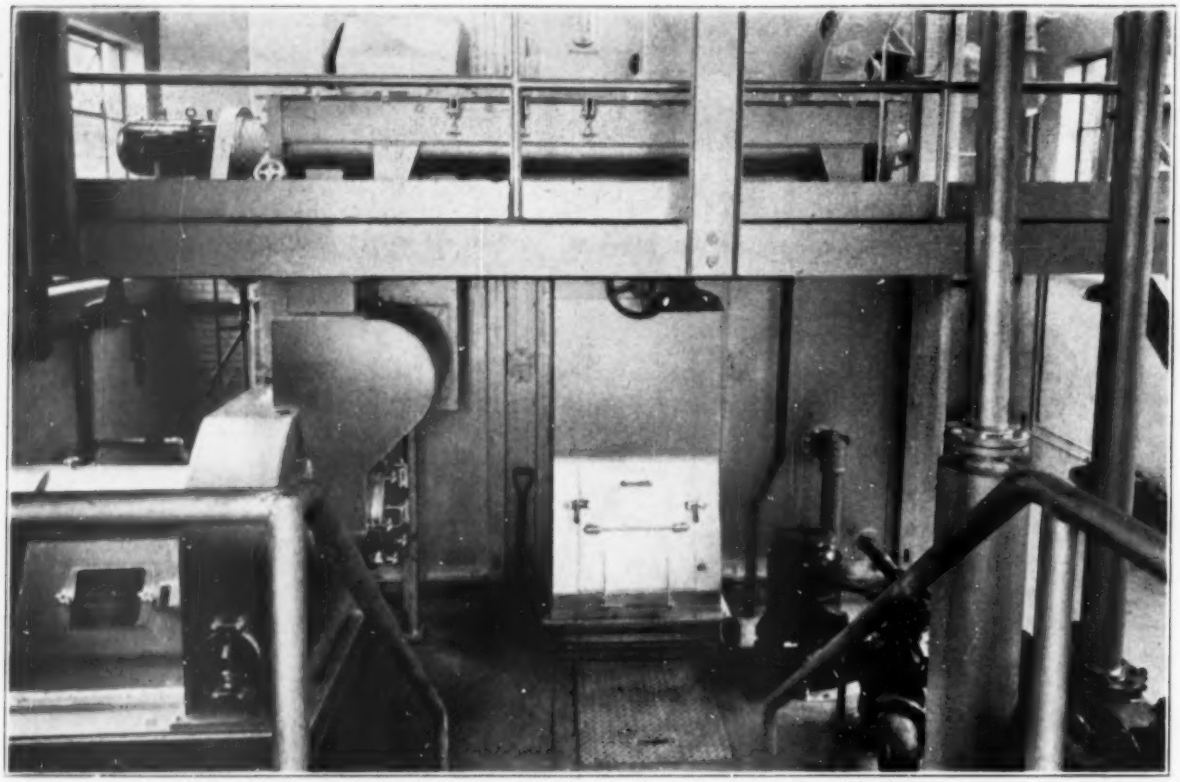
San Diego, Calif.

The first C-E Raymond unit at the San Diego plant was placed in operation during 1943. This unit has a rated capacity to evaporate 3,500 lb. of water per hour. Enlargements to the plant which were commenced in 1948 included an additional flash dryer with a capacity of 5,000 lb. of water evaporated per hour.

The experiences in operation at this plant due to wear from quantities of sand in the sludge removed have been somewhat similar to those at Buffalo.

One of the problems that has been peculiar to the San Diego plant has been the prevention of explosions which would occur from time to time during the shutdown period. In accordance with the manufacturers' recommendations, facilities have been provided to permit flooding the system with steam during shutting down procedure or at times of power failure. The same protection can be afforded by the injection of water through fog nozzles. The manufacturers have commented that this system, in common with all flash drying systems, is equipped with a relief vent on top of the cyclone. They state that this relief vent will safely relieve explosions of any kind and without any danger to the operating staff. This latter is evidenced by the fact that over 10 to 12 years' experience with operation of these plants there is no reported case of damage to the equipment or injury to an operator from such source. However, it is reported that these "puffs" are demoralizing to operating personnel and the manufacturers state that provisions for injection of steam or water is a simple and convenient way of rapidly cooling down the system without damage to the equipment or furnace and is a very desirable convenience. At San Diego, the injection is made at the entrance to the dryer cyclone and cage mill.

The new installation includes a reinforced concrete brick-lined exhaust tunnel and 150-ft. stack for removal of dryer gases. There have been several fires in the tunnel and lower part of the stack. It appears that the operation of water sprays throughout the length of the tunnel and at the bottom of the stack has eliminated this difficulty. It is reported that the trouble in the tunnel was due to build-up of grease from ¼ to ¾ in. in thickness. This matter of grease in the sludge is an ever increasing problem in the operation of sludge handling and disposal units since the end of World War II. It is generally believed to be the result of the increasingly wide use of detergents. The manufacturers report that this trouble is not confined to any one plant or one location but that it is rather general. A grease content in the dry sludge up to approximately 8 percent will give no trouble. However, when this percentage is substantially exceeded, the very low temperature volatile fractions of the grease are distilled off and will condense on any cool surface. If not continuously removed, it may be ignited at some time during the period of the shutdown of the system. To preclude such the safe thing to do is to clean this part of the equipment either continuously by the



Cuyahoga Falls, Ohio—Small flash drying and incineration unit for handling raw sludge

use of water sprays or periodically by scraping.

A further reference to this problem of grease accumulation is given in the discussion of the operation of the Los Angeles plant.

Eric V. Quartly, superintendent of the San Diego sewage treatment plant, reports that while many operating problems have been experienced with the flash dryers during past years, he does not wish to convey the impression they are unsatisfactory for the purposes intended. On the contrary, he states these units are giving excellent service at the present time.

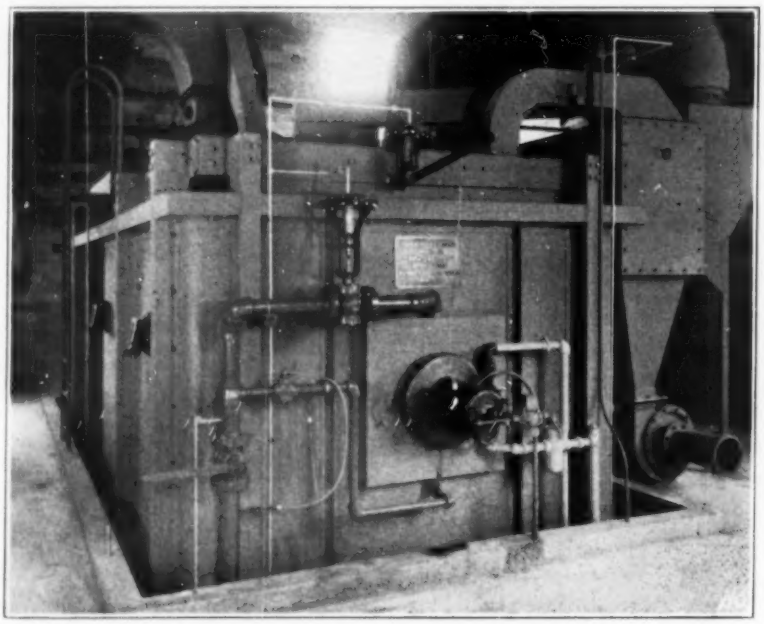
Los Angeles

The flash drying and incinerating equipment at the Los Angeles Hyperion plant includes four units each having a capacity to evaporate 22,500 lb. of moisture per hour from sludge cake containing 25 percent solids. Each unit was specified to be capable of incinerating all or any portion of the material dried by it.

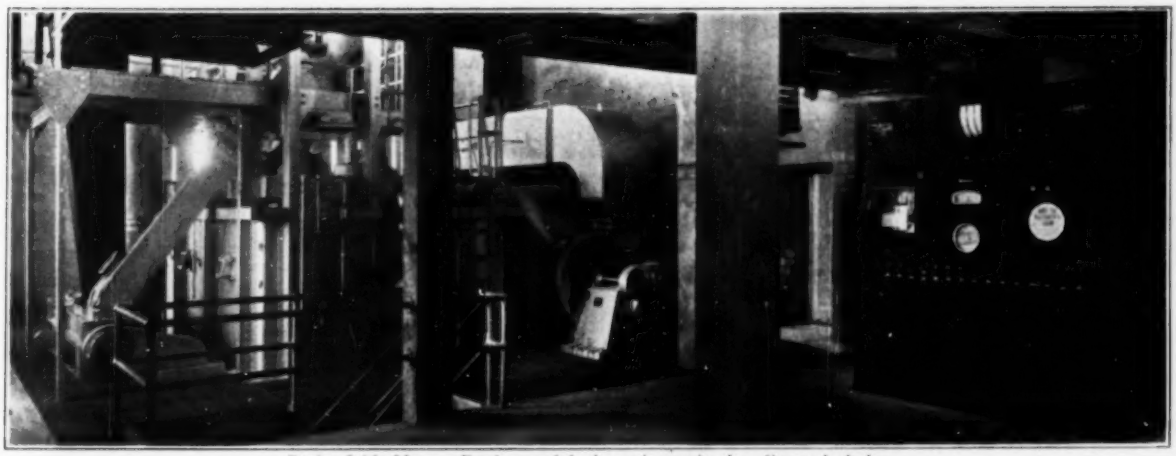
The equipment was first placed in operation during August, 1950. In a recent operational test conducted by the City, the average evaporation was 22,280 lb. of water per hour while producing fertilizer at the rate of 8,670 lb. per hour with an average filter cake load of 31,700 lb. per hour. The dryer inlet temperature was 1,112 deg. F. as compared with a design temperature of 1,300 deg. F. It is possible that if the design temperature was maintained at the dryer inlet, the evaporative capacity would be well in excess of the guaranteed figure.

During the month of May, 1951, the dryers reduced all of the filter cake produced at the plant to fertilizer amounting to 4,000,000 lb. for the month (moisture content 7 percent). Since the dryers were operated for only 23 percent of the time, there was no need to operate them at their rated capacity. The average moisture evaporated was 14,550 lb. per dryer. The dryer units at this plant have indicated that they can take care of all of the sludge produced on a design basis and with one spare unit.

As at the San Diego plant, there is some evidence of accumulation of grease which appears to have occurred when the digested sludge contained a reported average of 15 percent grease. Recently, the temperatures



Sheboygan, Wis.—Flash drying system for producing digested sludge fertilizer



Springfield, Mass.—Drying and incineration units for digested sludge

within the digestion tanks have been raised from an average below 90 deg. to about 95 deg. At the higher temperature, it appears that the grease content in the digested sludge will average approximately 5 percent. It is hoped that this will eliminate in large measure the grease problem on the walls of the flash drying equipment.

Summary

GENERAL. Equipment handling sewage sludge should be so designed as to resist wear from the abrasive particles contained therein. Parts subject to wear should be readily replaceable or provision made to build up the worn parts with abrasive resisting materials.

PREHEATERS. Adequate provision should be made for cleaning, maintenance, and repair of preheaters in connection with flash drying furnaces.

MIXERS. The mixers designed for mixing dried sewage with wet sludge cake should have abrasive and corrosion-resisting liner plates. The paddles should be of meehanite or other steel alloy capable of resistance to wear at high temperatures. Shafts and paddles should be readily replaceable and it is desirable to supply the paddles with easily replaceable abrasive resisting tips.

CAGE MILLS. The inlent end of the cage mill should be lined with a corrosion-resisting alloy. The cage mill should be of quick-opening design in which the rotor and pedestal may be rolled back on a track thus facilitating the replacement of liner plates and the replacement of cage bars.

INDUCED DRAFT FANS. These fans should be installed on the clean air side of the ash cyclones where practical.

DUCTS. The ducts and pipes carrying sludge in suspension should be fabricated in easily removable sections. The bends should be provided with removable wear backs lined with abrasive resisting material such as chrome ore.

PURGING SYSTEM. A suitable system of water or steam purging for prevention of explosions in the system should be provided.

CYCLONE SEPARATORS. A lining is required which will resist abrasion. A 2-in. gunite mixture of lumnite cement and trap rock appears to be suitable for this purpose.

STACKS. It appears desirable to line chimneys taking the discharge from the flash dryers and incinerator with firebrick for at least the lower ⅓ of their height. Consideration should be given to the fact that occasional high temperatures may occur in the operation of incineration equipment.

FLY ASH REMOVAL. Fly ash may create a serious problem in the gas discharged from the fly-ash drying systems unless appropriate means are provided for its removal. It has become increasingly necessary in the case of new installations to comply with stringent fire, smoke and air pollution ordinances. Enlarged ducts, settling chambers or inertia separators seldom would prove to be satisfactory.

Mechanical dust removal equipment such as the Multiclone type as manufactured by Western Precipitation Corp. or the fly ash collectors using the Van Torgeren system as manufactured by Buell Engineering Co., or the Thermix Controlled Multi-Clone type as manufactured by the Prat-Daniel Corp. usually afford satisfactory results for this service. However, in some cases, a higher degree of treatment must be provided for the removal of fly ash, such as electrostatic precipitation.

This latter type of equipment must be carefully designed to permit access for cleaning. If continuously high efficient removal of fly ash particles and smoke is required, sufficient units for fly ash removal must be provided so that one unit may be taken out for repair and maintenance.

Acknowledgment

Acknowledgment is gratefully made for data supplied by John P. McDonald, Sewage Treatment Plant Engineer, Springfield, Mass.; Eric V. Quartly, Superintendent, Sewage Treatment Works, San Diego, California, and to C. W. Gordon, Manager, Flash Dryer Division, Combustion Engineering-Superheater, Inc.

TEN PACKING "DONT'S" WORTH HEEDING

It is well known that "don'ts" are often more effective than "do's," so here are some suggestions and warnings arranged as "don'ts" that are based on many years of practical experience. They will be found useful in connection with the selection and installation of packings. To follow them may mean freedom from trouble that would occur when even the best obtainable packing is improperly installed.

1—DON'T fail to make clear what the packing is to pack. In other words, with what will the packing make contact?

2—DON'T guess at a size, diameter, width or height when ordering packings. Many failures have resulted from small errors in dimensions.

3—DON'T allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall; 1/16 to 3/32 inch on each side, depending on size of packing, is usually recommended.

4—DON'T doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.

5—DON'T apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean so sediment will not collect in cylinders and wear the packiñg.

6—DON'T apply cup packings to end of plunger which is badly worn; pressure will force the packing down into clearance between plunger and clyinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.

7—DON'T apply "U" packings where plungers are worn without reinforcing under heel with leather cushion rings.

8—DON'T look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.

9—DON'T allow water to corrode cylinder walls, plungers or rods. Use an anti-rust agent that will prevent this and that will act as an effective lubricant.

10—DON'T squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set glands up to point where "U" packaings are free to function properly.

Contributed by *W. F. Schaphorst*, M. E., Newark, N.J.

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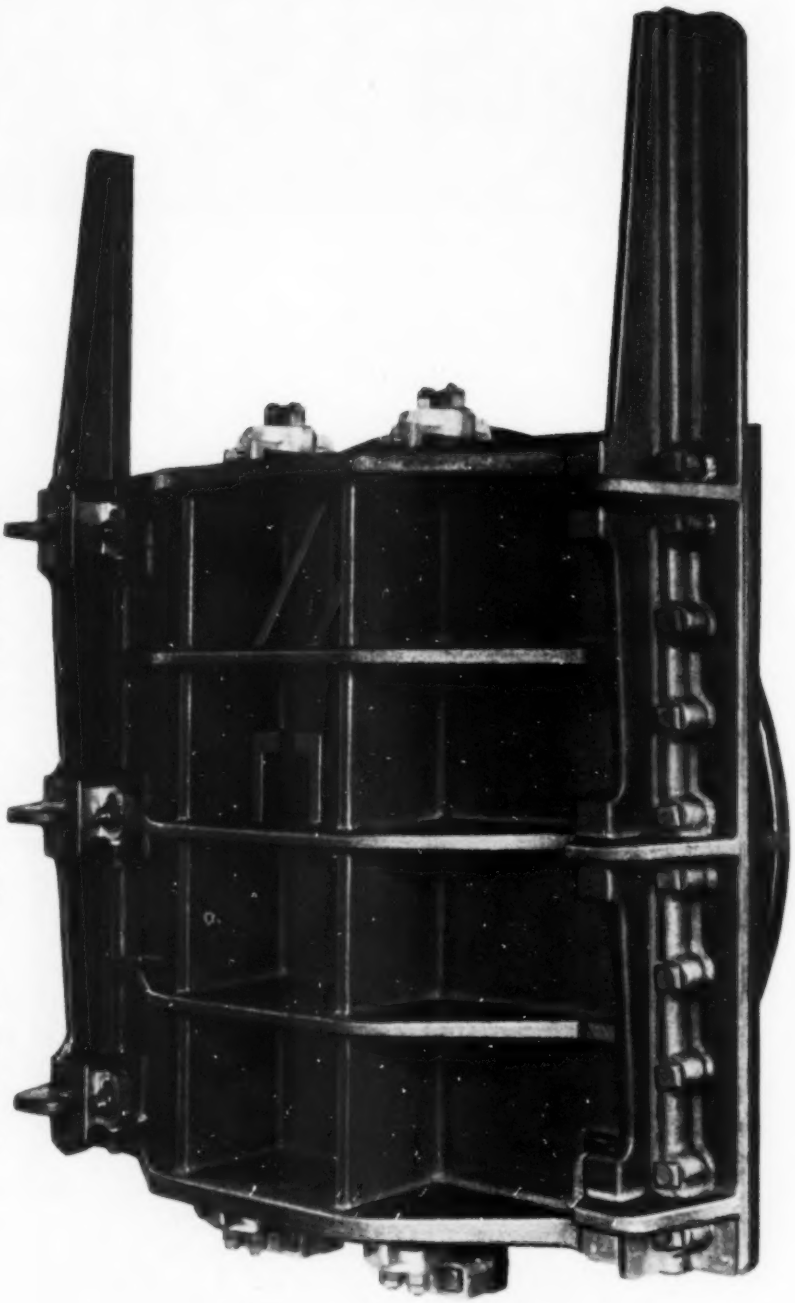

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Consult Bulletin 753 for complete data and specifications.

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OIL WASTE EXCLUSION FROM SEWERS

Baltimore Experiences with a Workable Ordinance

C. E. KEEFER
Prin. Asst. Engr.
Bureau of Sewers, Baltimore, Md.

IN 1927 a fire near the outlet of the largest storm drain in Baltimore resulted from the escape of gasoline and oil into the drain. Causing no serious damage, it did, however, result in passage of a city ordinance requiring daily storage of waste oil, crankcase drainings and greases in approved steel drums by all users of such materials.

The Baltimore Ordinance No. 1083

An ordinance to regulate the handling, storage, transportation and disposition of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind upon all premises in Baltimore City; providing for enforcement, and also providing a penalty for violation of the provisions of this ordinance.

Section 1. Be it ordained by the Mayor and City Council of Baltimore, That from and after the date hereinafter provided, the following rules and regulations shall apply to the handling, storage, transportation and disposition in the City of Baltimore of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind:

(a) All waste oils, including crank case drainings, shall be immediately taken up and deposited and kept while on the premises in steel drums, the character, size construction, number and location of which shall be from time to time prescribed by the Board of Fire Commissioners of Baltimore City, or in containers of other construction approved by the Chief Engineer of Baltimore and by the said Board.

(b) All waste greases shall be collected at least once daily and deposited and kept as in the manner provided for waste oils in the preceding paragraph, and in no case shall any waste greases be permitted to remain in or about any premises over night, except when so deposited.

(c) All such drums, containers and their appurtenances shall be kept and maintained at all times in first class condition and tightly closed so as to prevent the escape of any of the contents thereof, and shall be used for no purpose other than the storage and transportation of waste oils and greases.

(d) The Mayor and City Council, acting through the Chief Engineer of Baltimore, shall determine from time to time the agencies by or through which all such drums, containers and/or the contents thereof shall be removed, stored, transported and disposed of, and the times when, the places where and the manner in which the same shall be done, and such determination shall be subject to the approval of the Board of Fire Commissioners of Baltimore City; and no such drums, containers and/or contents shall be removed, stored, transported or disposed of in any other manner or through any other agency.

Section 2. And be it further ordained, That this ordinance shall not be construed to prohibit the sale and/or reclamation of waste oils and greases, provided, on such sale and/or reclamation, said waste materials are otherwise handled, stored, transported and disposed of in accordance with the terms and provisions of this ordinance and any rules and regulations made in pursuance thereof.

Section 3. And be it further ordained, That terms used in this ordinance are hereby defined as follows:

The term "waste oils and greases" shall include all oils and greases which, by reason of previous use in and about vehicles, machinery or appliances of any kind, are in such condition as to be unfit for further use for such purposes without reclamation.

The term "premises" shall include all real and leasehold property where such vehicles, machinery, or appliances of any kind are used, operated, cleaned, repaired or serviced.

The term "person" shall include persons, firms and corporations.

Section 4. And be it further ordained, That any person violating any of the provisions of this ordinance shall be subject to a fine of Fifty Dollars ($50.00) for each and every offense.

Section 5. And be it further ordained, That the Board of Fire Commissioners of Baltimore City are hereby charged with the duty of enforcing the terms of this ordinance.

Section 6. And be it further ordained, That all ordinances, or parts of ordinances, inconsistent with the provisions of this ordinance be, and the same are hereby repealed to the extent of such inconsistency.

Section 7. And be it further ordained, That in the event that any word, phrase, clause, sentence or section of this ordinance shall be declared invalid by any court, the remainder of the ordinance shall not be affected thereby, but shall remain in full force and effect.

Section 8. And be it further ordained, That this ordinance shall take effect three (3) months after the date of its passage and approval.

Approved May 11th, 1927.
HOWARD W. JACKSON, Mayor.

Attest: A True Copy:
JOHN A. SLOWIK, City Librarian.

Collection Contracts

In order to provide for the collection of these materials the city entered into a two-year contract with a collection company. Since the first contract expired, Sept. 30, 1929, the work has been done by three companies at different times. The cost to the city is shown in the accompanying table.

During this sixteen-year period 4,287,714 gallons of oil and greases have been collected. This is equivalent to 263,860 gallons yearly at an average cost of 7.5 mills per gallon.

Cost of Collecting Grease and Oil in Baltimore from 1927 to 1943

Year	Contractor	Amount paid contractor	Grease and oil collected, gal.
1927	Provident Oil Service Co.	$ 810	71,701
1928		3,240.00	265,000
1929		3,037.50	318,000
1930		2,430.00	286,850
1931		2,430.00	280,100
1932	Thomas Leonard	2,422.50	229,299
1933		2,400.00	139,804
1934		2,400.00	143,280
1935		2,300.00	155,690
1936		2,000.00	169,515
1937		2,000.00	156,150
1938		1,625.00	120,940
1939	City Waste Oil Co.	500.00	327,440
1940		500.00	437,420
1941		768.75	473,420
1942		1,575.00	416,099
1943		1,575.00	297,006
	Total	$32,013.75	4,287,714

The contractor is required to furnish steel drums for the storage and transportation of oil and greases where the amount collected is more than 20 gallons weekly. For lesser quantities, the containers are furnished by those who must dispose of the oil or grease. Containers must be collected within 24 hours after they are full.

The present contractor has three 1,000-gal. tank trucks for the transportation of the materials. Each truck is equipped with a suction and a discharge pump for handling the oils.

Oil Purification Plant

Oil is discharged from the tank truck into an underground storage tank, from which it is pumped into a 2,000-gal. dehydrating tank containing steam coils. Moisture evaporation is accomplished by passing steam at 90 lb. pressure through the coils for a period of five to eight hours.

Dehydration is followed by sulfuric acid treatment in a 1,500-gal. storage tank. Sludge precipitated from the oil is disposed of in a lagoon. Clay is added to the partially purified oil which is then cooked with steam at about 600 deg. F. for eight to ten hours. During the cooking the higher volatile hydrocarbons such as kerosene, naphthalene, and the alcohols are distilled off for use as fuel in the steam generating plant.

The oil residue is cooled to approximately 200 deg. F. and filtered in a Shriver plate press, producing a filtrate equal in quality to new oil and ready for sale. About 12 hours are required to complete the process.

The collection and purifying of oil is not unique with Baltimore as similar plants are in operation in New York City, Philadelphia and elsewhere. The unique feature about the practice is that Baltimore has adopted an ordinance requiring daily collection and disposal of greases and oils and has made the necessary provision for having the work done. Since this ordinance has been in effect the sewers in the city have been remarkably free from inflammable materials.

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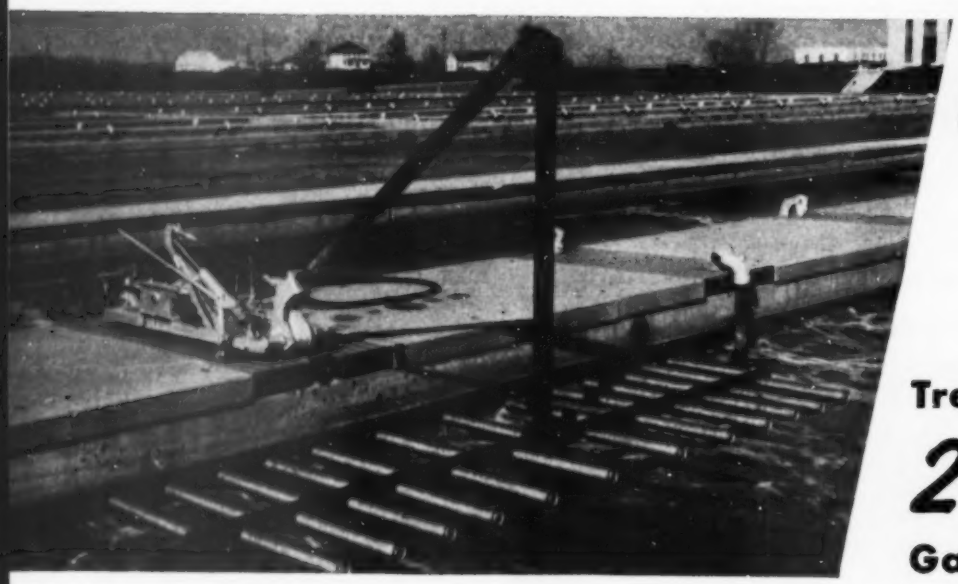
IN 261 PLANTS



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Leading consulting and design engineers and plant operators agree that Chicago Swing Diffuser Systems offer important exclusive advantages for new plants. And, in addition, they provide a logical solution where existing aeration systems are inadequate. Here are a few reasons why . . .

ACCESSIBILITY . . . Individual swing units are easily raised for inspection and diffuser cleaning.

CONTINUOUS PERFORMANCE . . . Only with Chicago Swing Diffusers can uninterrupted operation be assured without costly stand-by aeration tanks.

ECONOMICAL OPERATION . . . Lowest cost simplified cleaning restores new tube performance, permitting maintenance of lower blower pressures.

EFFICIENT AERATION . . . Wide-band air diffusion provides greater contact volume of diffused air with tank liquor and the longest contact period. No unaerated center core.

Complete operating histories and test data on Chicago Diffuser Systems are available for your review.

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SEWAGE EQUIPMENT DIVISION

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Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

ACTIVATED SLUDGE PLANT OPERATION*

By T. R. HASELTINE

Partner, The Chester Engineers, Pittsburgh, Pa.

THE impurities in sewage are present in three forms: suspended, colloidal, and dissolved. Only the heavier suspended matter can be removed by plain sedimentation. The cloudiness of sewage is due to the colloids and finely divided suspensoids.

Nature of Activated Sludge

When settled sewage is aerated for protracted periods, those particles will coalesce to form light feathery floc, which settles slowly upon quiescent standing. The supernatant liquor will be relatively clear. If that liquor is discarded and the thin sludge is reaerated in a second batch of settled sewage, a shorter period will suffice to produce clarification and more sludge will result. If this cycle is repeated several times, it will be found at first, that as the amount of sludge increases, the clarification time decreases, but eventually a point will be reached beyond which further increments of sludge are of little or no value in reducing clarification time. At that point clarification may occur in 10 to 30 min.

During the process of flocculation and clarification many of the bacteria and protozoa in the sewage are adsorbed on or enmeshed in the floc. In the presence of abundant dissolved oxygen some forms die off, or remain dormant, while others multiply rapidly. By the action of their growth these organisms convert the pollutants adsorbed on the sludge or dissolved in the sewage to carbon dioxide, sulfates, nitrates, and the living protoplasm of their own bodies. This process is termed biological oxidation. During its progress bacterial enzymes are secreted which hasten clarification.

It is important to remember that flocculation, clarification, and oxidation, as encountered in the activated sludge process, are dependent upon biological activity, which in turn is dependent upon oxygen. Without that biological activity flocculation would be slower, clarification would be less complete, and oxidation might not occur at all.

Both oxidation and clarification take place most rapidly when the sludge and sewage are first brought together, providing there is sufficient oxygen available. But, unlike clarification, oxidation cannot be completed in a few minutes—several hours, or even days, are required for that. Unless sufficient time is allowed between cycles for oxidation to catch up with adsorption, the settleability of the sludge deteriorates and, if oxidation continues to lag, the clarifying power of the sludge is also reduced.

Classification of Activated Sludge Processes

There are several different modes of operation or degrees of treatment that conform to the accepted definition (1) of the activated sludge process.

In the early days all activated sludge plants were expected to produce a clear, highly nitrified effluent containing less than 10, and frequently less than 5, p.p.m. of 5-day B.O.D. or suspended solids. In such a plant a non-nitrifying sludge was obviously unsatisfactory. Later many authorities concluded that nitrification was unnecessary. It was found that at most plants considerable reduction in air, and hence power consumption, could be made if nitrification was avoided. The effluents from these plants still had about the same suspended solids and B.O.D. as those from the nitrifying process. Both of these processes are termed "conventional" process and both yield about 90 per cent reductions in applied B.O.D. when treating a presettled typical municipal sewage.

A later development has been the so-called high-rate activated sludge process, which does not attempt to produce a high quality effluent. When treating a typical municipal sewage it yields an over-all B.O.D. reduction of about 75 per cent, which is equivalent to about 60 per cent on the basis of settled sewage.

Still farther down the ladder of B.O.D. removal, are straight aeration plants with relatively long aeration periods. Although these plants return no sludge to the aerators, their aeration periods are so long that the floc formed in the aerators may have appreciable biological activity. These plants may yield over-all B.O.D. reductions of 60 per cent, or about 40 per cent on the basis of the applied settled sewage (2) (3).

Recently the so-called "Biosorption Process" has been announced. Like some of the earlier activated sludge plants, this process omits any primary treatment other than screening and grit removal. According to the flow sheet for this process, equal volumes of normal crude sewage and activated sludge are intimately mixed for 35 min., after which the mixed liquor enters a conventional settling basin. Settled effluent is discharged to the stream. Sludge withdrawn from the settling tanks is passed through a "sludge stabilizer" or "aerobic digester" having a 2½-hr. aeration period before it is again mixed with crude sewage. The "sludge stabilization" or "aerobic digestion" is simply sludge reaeration under a new name. Sludge reaeration has been used in either nitrifying or non-nitrifying conventional plants and also in some high-rate plants. In the author's opinion, the newest things about the Biosorption Process are the names used and the short contact period between sludge and sewage.

Regardless of the particular type of activated sludge process under consideration, much the same control tests are used. However, their significance and the interpretation of their results may differ, depending upon the degree of treatment being sought. The various control tests most commonly used are (a) those to regulate aeration, (b) those to control the amount of sludge, and (c) those to measure the condition of the sludge.

Dissolved Oxygen Tests

Dissolved oxygen tests are by far the best and perhaps the only logical method of controlling aeration. In any aeration tank there are two opposing forces—the aerator device injecting air (oxygen) into the sewage-sludge mixture, and the biological organisms using oxygen in their life processes. So long as the first force exceeds the second, there will be some dissolved oxygen in the mixed liquor and so the operator can be reasonably certain that aeration is adequate. If there is no dissolved oxygen present then the reverse is true, no matter how much air is being applied.

The oxygen requirements depend primarily upon the amount and condition of the sludge present, and are always greatest at the point where the sludge and sewage first come in contact with one another. When considerable sludge is being carried, the variations in volume and strength of the sewage have little, if any, influence on the air requirements and so aeration may continue at a practically constant rate. When lesser amounts of sludge are carried, there will be some hourly variation in oxygen requirements. Under those conditions, and in larger plants, the saving in power resulting from intelligent variation in air supply may be sufficient to warrant making dissolved oxygen determinations several times a day. However, in small plants, or those carrying a high concentration of sludge, one set of determinations per day, preferably about 6 hr. after the peak sewage load reached the aerators, should suffice.

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The dissolved oxygen determinations should be made at various points from inlet to outlet of the aerators. At least in conventional plants, it is desirable to always have at least a trace of oxygen at the inlet end and gradually increasing amounts at succeeding points along the aerator. If a highly nitrified effluent is desired, it may be desirable to maintain as much as 3 to 6 p.p.m. of oxygen at the aerator outlets, but where nitrification is not desired 1 or 2 p.p.m. is probably adequate.

Because oxygen requirements are greatest when sewage and sludge first come together, it is frequently necessary to apply more air at the inlet ends of the aerators and gradually decrease aeration toward their outlets. This is termed "tapered aeration." Another solution to the problem is "step aeration," where either or both the return sludge and the sewage are introduced at several different points along the aerators (4) (5). Most plants have not been designed to permit use of step aeration.

Where sludge reaeration tanks are used, the air supply to them should be so adjusted as to maintain about the same dissolved oxygen as recommended for conventional mixed liquor aerators. One reason sludge reaeration tanks have come into ill repute is the fact that the solids concentration in them, and hence their oxygen requirements, are so high that it is virtually impossible to maintain any dissolved oxygen in them. Under such conditions retention of sludge in those tanks did more harm than good.

Retention of sludge in the bottom of final sedimentation basins is even more harmful. Some operators make routine measurements of sludge depths in final tanks and vary the rate of sludge withdrawal so that those depths never exceed 2 ft. Even lesser depths may be desirable.

By using sludge return rates as high as 50 per cent, or even 100 per cent, it is possible not only to avoid sludge build-up in final tanks, but also to dilute the sewage-sludge mixture at the aerator inlets (or the sludge in reaeration tanks) so that oxygen requirements will not be so great at those points. This is an alternative to either tapered or step aeration that is particularly applicable to small plants.

Amount of Sludge

The amount of sludge present in the mixed liquor is most accurately measured gravimetrically by making suspended solids determinations. Originally it was usually measured volumetrically by observing the percentage of sludge in a graduate of mixed liquor after a definite standing time. The objection to this method of measurement is that the volumetric reading is affected almost as much by settling characteristics of the floc as it is by their weight. If both methods of measurement are used, it is possible to calculate the "sludge index," which is a useful indicator of sludge condition.

Centrifuging is a third method of sludge measurement. It is more rapid than the other methods, but less accurate than the suspended solids test. All three methods are more fully discussed elsewhere (6).

The proper amount of sludge to carry depends upon the degree of treatment desired and the capacity of the aeration equipment. Generally speaking, diffused air plants can carry more sludge than those depending upon mechanical aerators. Typical mixed liquor solids concentrations for normal sewage are probably about as follows:

Conventional nitrifying plants, 3,000 p.p.m. or more.

Conventional non-nitrifying diffused air plants, 1,000 to 2,500 p.p.m.

Conventional non-nitrifying mechanical aeration plants, 600 to 1,500 p.p.m.

High-rate plants, never over 600 to 800 p.p.m., and frequently as little as 200 to 300 p.p.m.

Straight aeration plants usually have a higher solids concentration in the mixed liquor than in the settled sewage, despite the fact that they have no sludge return; perhaps 100 p.p.m. would be typical.

At present, frothing in aerators is generally attributed to detergents in the sewage. However, low solids concentrations at least aggravate the problem. The author encountered foaming at Salinas, Calif., whenever the solids were low, back in 1930 before the use of detergents was common.

Measures of Sludge Condition

Sludge Index

By far the most common measure of sludge condition is the sludge index, which is the ratio of the percentage of sludge by volume after standing 30 min. to the percentage of sludge by weight as measured by the suspended solids determination. It is a measure of the settling characteristics of the sludge; a high index indicates poor settleability, and *vice versa*.

A bulked sludge is simply a sludge that, after a given settling period, occupies a greater volume than would a normal sludge containing the same weight of suspended solids. Bulking is best measured by the sludge index. Whether or not a bulked sludge will pour over the weirs of final settling tanks depends upon the design of those tanks and the amount of sludge being carried. The more generous the design of the tanks, the higher the sludge index that can be tolerated in a given mixed liquor solids concentration (or, for a given index, the higher may be the solids concentration) before the tank effluent becomes fouled with sludge.

In conventional plants, either nitrifying or non-nitrifying, the primary cause of bulking is the failure of biological oxidation to keep pace with adsorption. The reason for that lag may be too short an aeration period, inadequate air supply, increased pollution load on the plant, insufficient sludge, septic sewage or return sludge, germicidal waste, excessive oil and grease, etc. Unless the cause is found and corrected, the sludge index increases, bulking occurs and, if it continues, the final effluent will eventually become fouled with sludge. In that event, the operator must reduce the amount of sludge he is carrying, even though the initial cause of the lag in oxidation may have been insufficient sludge. The net result of operation with a reduced amount of sludge will be a lower degree of treatment than had been hoped for.

High-rate activated sludge plants generally have a higher sludge index than do the conventional plants. However, when oxidation lags sufficiently behind adsorption for a considerable period of time, clarification itself is reduced. In such cases, the sludge index is lower than it is when there is less lag. Since such is the case, an increase in sludge index at a high-rate activated sludge plant may indicate the need for reducing, rather than increasing, the aeration period or the air consumption.

A slight excess of oxidation over adsorption favors nitrification and results in a low sludge index. However, too great an excess produces a dense "pin-point" sludge that does not yield as clear an effluent as does the more flocculent sludge with a higer index. This may be another objection to sludge reaeration in conventional non-nitrifying plants. However, it is believed that in any properly designed and operated conventional plant sludge reaeration can be used to advantage.

Sludge Age

A less common measure of sludge condition is sludge age. As usually calculated, the sludge age is the ratio of the total weight of activated sludge solids in the plant to the weight of suspended solids removed from the daily flow of settled sewage. Theoretically, at least, it might be more accurate to use the weight of total rather than suspended solids removed from the settled sewage. There may be other objections to the term, also. However, it has proved a useful tool in controlling some plants. Generally speaking, the older the sludge, the lower will be its sludge index and the higher will be its ash content. Only old sludges can be nitrifying sludges, because nitrification does not take place until after much of the carbonaceous material has been oxidized.

Volatile and Ash Content

The routine determination of ash or volatile matter in the return sludge is also a useful indicator of when to expect a change in sludge index. There does not seem to be any universal optimum volatile content for all plants. But, in most conventional plants, a rise in volatile content of the return sludge precedes a rise in sludge index and *vice versa*. Apparently this relationship does not necessarily hold for high-rate and/or straight aeration plants.

Microscopic Examination

Microscopic examinations of sludge are of value in conventional plants—particularly observations of the number and type of protozoa. Unless there is a preponderance of the larger ciliate protozoa over the smaller flagellates the operator can be certain that oxidation is lagging behind adsorption.

Miscellaneous

Other tests that are sometimes used to measure the condition of the sludge include measurements of its short-time oxygen requirements, comparisons between the dissolved solids concentrations in the settled sewage and in the plant effluent, grease determinations, etc. Oxidation potential may also be a useful tool, not only to measure sludge condition, but also to control aeration.

References

1. "Glossary, Water and Sewage Control Engineering." A.P.H.A., New York, N.Y. (1949).
2. Hatfield, W. D., "Operation of Pre-Aeration Plant at Decatur, Illinois." *Sewage Works Jour.*, 3, 4, 621 (Oct., 1931).
3. "The Operation and Control of Activated Sludge Sewage Treatment Works." A.P.H.A. Committee Report, *Sewage Works Jour.*, 14, 1, 19 (Jan., 1942).
4. Gould, R. H., "Operating Experiences in New York City." *Sewage Works Jour.*, 14, 1, 70 (Jan., 1942).
5. McKee, J. E., and Fair, G. M., "Load Distribution in the Activated Sludge Process." *Sewage Works Jour.*, 14, 1, 121 (Jan., 1942).
6. Haseltine, T. R., "Operating Fundamentals of the Activated Sludge Process." *Water and Sew. Works*, 98, 4, R-144, (1951).

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ACTIVATED SLUDGE TREATMENT

BIO-ACTIVATION PROCESS—a patented system utilizing the best qualities of trickling filters and activated sludge. Pre-treatment (pre-aeration and grease flotation) is employed to increase the efficiency of primary settling so as to prevent overloading of secondary treatment. Primary treatment is followed by high capacity filters and short period intermediate sedimentation. Here, initial high removals of B.O.D. are obtained before sewage is passed to aeration tanks where activated sludge is developed. Because of the intermediate filter treatment which considerably reduces the strength of the primary effluent, the liquor can be readily handled by the activated sludge process without the usual upsets caused by exceptional conditions and shock loads.

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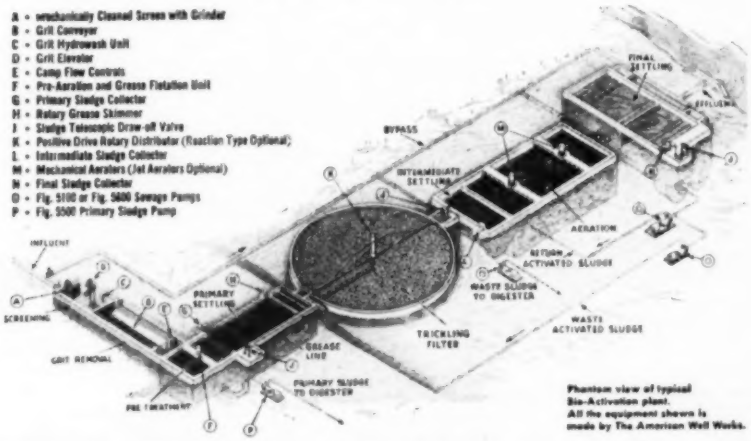

Phantom view of typical Bio-Activation plant. All the equipment shown is made by The American Well Works.

MECHANICAL AERATION—Consists of a circulating pump with downdraft tube and hydraucone assembly. As liquor passes through the pump, fine bubbles of air are drawn in and intimately mixed with the sewage. This mixture is ejected at high velocity across the tank floor. Consequently, entrained air is distributed uniformly across the tank, and fine air bubbles, rising slowly to the surface, supply sufficient oxygen to maintain the activated sludge process. For large installations, "AMERICAN" Aerators are installed in single, large tanks without dividing walls because the pattern of recirculation sets up hydraulic baffles between the units, thereby eliminating any possibility of short circuits.

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JET AERATION—Injects an intimate mixture of liquor and finely divided air into the aeration tank. No other method of aeration produces the unusually high rate of oxygen absorption at remarkably low cost. Additional aeration economically provided for existing plants. Present diffuser plate or tube installations easily replaced.

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Send for Technical Supplement "RD"

Send for Technical Supplement TV on Telescoping Sludge Valve

GRIT REMOVAL

AMERICAN CAMP REGULATOR—an adjustable control to maintain velocity of sewage flow thru grit channels at optimum rate, regardless of rate of flow thru plant.

GRIT CONVEYOR—single strand, drag type. Carries grit to hopper for washing and removal.

GRIT HYDROWASH—grit washed free of organic matter by turbulent downflow recirculation of liquor in grit hopper.

GRIT ELEVATOR—tube type, totally enclosed for lifting well-drained grit to desired height. Manual or automatic operation.

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American Camp Regulator for Grit Channels

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MECHANICALLY CLEANED BAR SCREEN AND GRINDER—designed for wide range of channel widths, settings, and arrangements. Grinder attached to sorting tray . . . shredded screenings returned to sewage flow.

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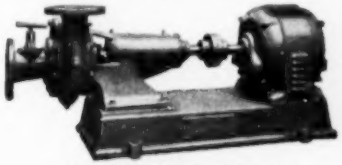
GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Send for Bulletin No. 260A*



No. 5500 Sludge Pump

SLUDGE REMOVAL

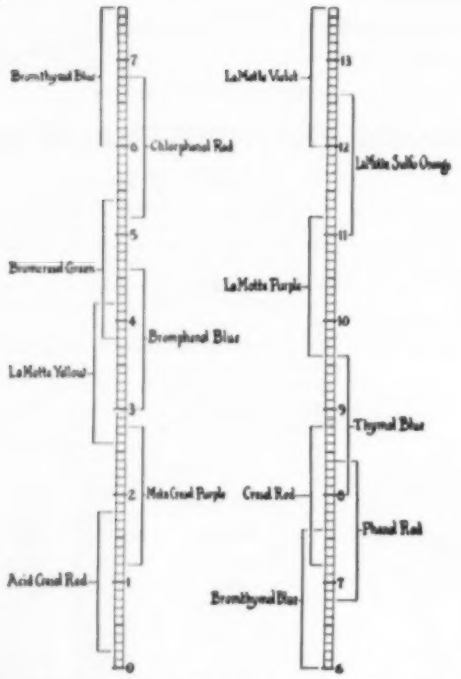
POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks.

CIRCULAR CLARIFIERS—for round settling tanks.

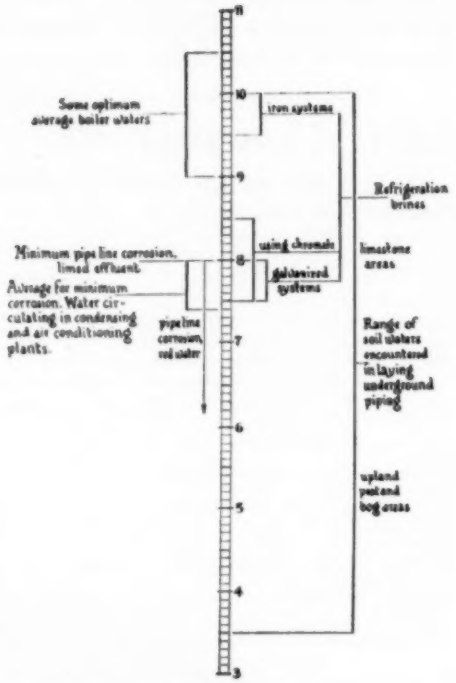
SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 3400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3" to 18" inclusive, in capacity from 40 to 10,000 GPM, and in head from 5' to 85'.

Send for Bulletins No. 237A, 250A, 253A, 261A

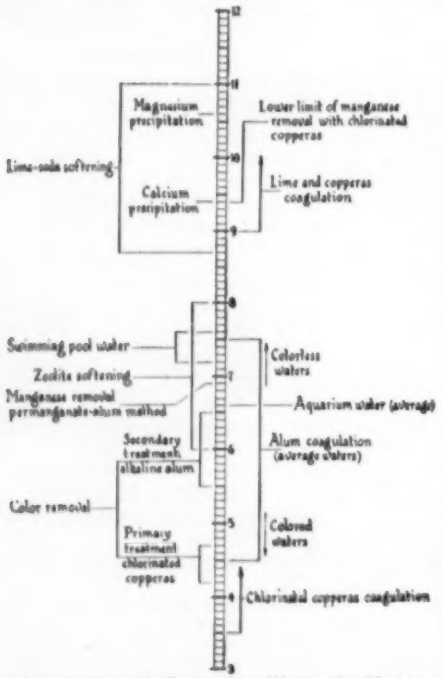
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



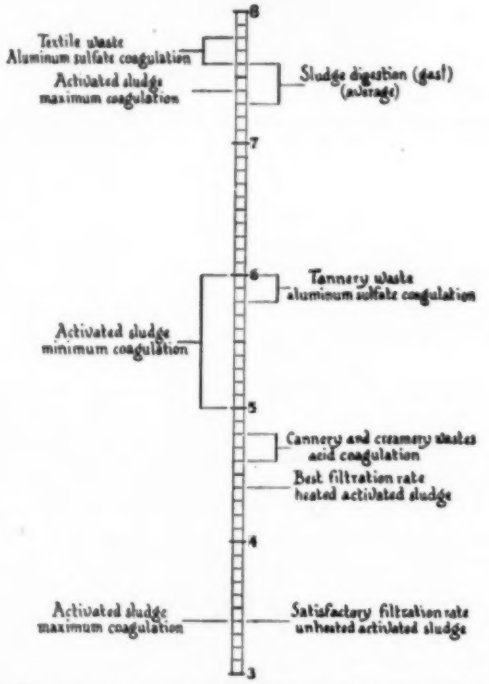
Ranges of Selected Indicators for pH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
using chromate
limestone areas
Minimum pipe line corrosion, limed effluent.
galvanized systems
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, soil water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification


Textile waste
Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas!) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins. Publishers, Baltimore, Md.)

APPLICATION OF THE SLUDGE VOLUME INDEX TEST TO PLANT OPERATION

By DON E. BLOODGOOD

Prof. of Sanitary Engineering, Purdue University

THE Sludge Volume Index (S.V.I.) as given in "Standard Methods for Examination of Water and Sewage" has been a much discussed test. The original idea of the test was to indicate the bulking of activated sludge. The units used increase with an increase in the volume occupied by the same weight of solids. As a qualitative test it has been very helpful and a desire has often been expressed to correlate the sludge index with plant operation data.

If it is assumed that the concentration of sludge, obtained in the bottom of a cylinder, in a sludge index test, is the maximum concentration that can be obtained in a reasonable settling period, without detriment to the activated sludge, it is believed that the results can be used in a mathematical calculation which is applicable to plant operation.

It is realized, however, that the S.V.I. data obtained in a 30-minute settling period may not be the same as might be found for a 60-minute period (Fig. 1). It has been found from experience that even with mixed liquor which settles exceptionally well the concentration of sludge in the bottom of the test cylinder may be slightly higher at the end of 60 minutes than it is at the end of 30 minutes. The indications are that for mixed liquors of poor settling qualities the difference between the concentration at 30 minutes and 60 minutes is even greater. It would seem, therefore, that if the sludge index (S.V.I.) were calculated on a 60-minute settling period the results would be more satisfactory when used in the following calculations.

If the settling cylinder is considered as a secondary settling tank and the settled sludge as return sludge, the sludge index (S.V.I.) may be expressed in per cent solids of the sludge. Then per cent solids in the bottom of the cylinder may be obtained by dividing 100 by the sludge index (S.V.I.). This relation may be seen in Fig. 2.

This graph would be of assistance in activated sludge plant operation if the only desire were to determine the maximum return sludge concentration possible as indicated by the sludge index determination. The matter of sludge solids balance, however, enters the considerations and it is necessary to take it into account in discussing plant operation problems.

Development of Formulae

In an analysis of the sludge balance, for any one day of activated sludge plant operation, it is quite evident that the amount of solids in the mixed liquor must be equal to the solids in the return sludge, assuming the waste sludge, incoming raw sewage solids and the loss of solids by oxidation are considered negligible quantities. The mixed liquor return sludge balance may be expressed by the formula:

$$(a + b)x = b\,(y) \qquad (1)$$

a = sewage flow mgd.
b = return sludge flow mgd.
x = mixed liquor solids in %
y = return sludge solids in % (or solids in the bottom of settling cylinder)

If the sludge volume index be represented by (z), then, as above explained,

$$y = \frac{100}{z} \qquad (2)$$

The per cent by volume of return sludge may be expressed by the formula:

$$m = \frac{b}{a} \times 100 \qquad (3)$$

By simple algebraic substitutions of Formulae (2) and (3) in Formula (1) it may be written:

$$m = \frac{100}{\frac{100}{zx} - 1} \quad \text{or}$$

$$z = \frac{m}{(1 + .01\,m)x}$$

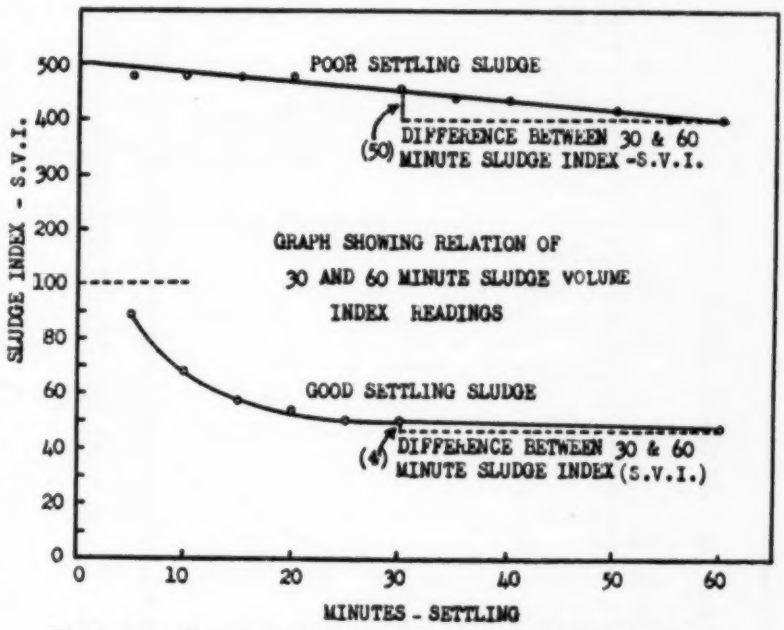


Fig. 1. Graph Showing Relation of 30 and 60 Minute Sludge Index Readings.

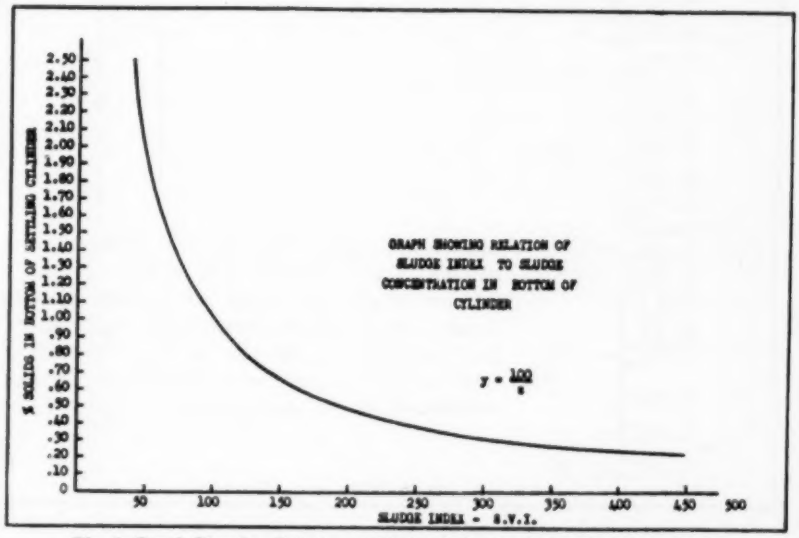


Fig. 2. Graph Showing Relation of Sludge Index to Sludge Concentration in Bottom of Cylinder.

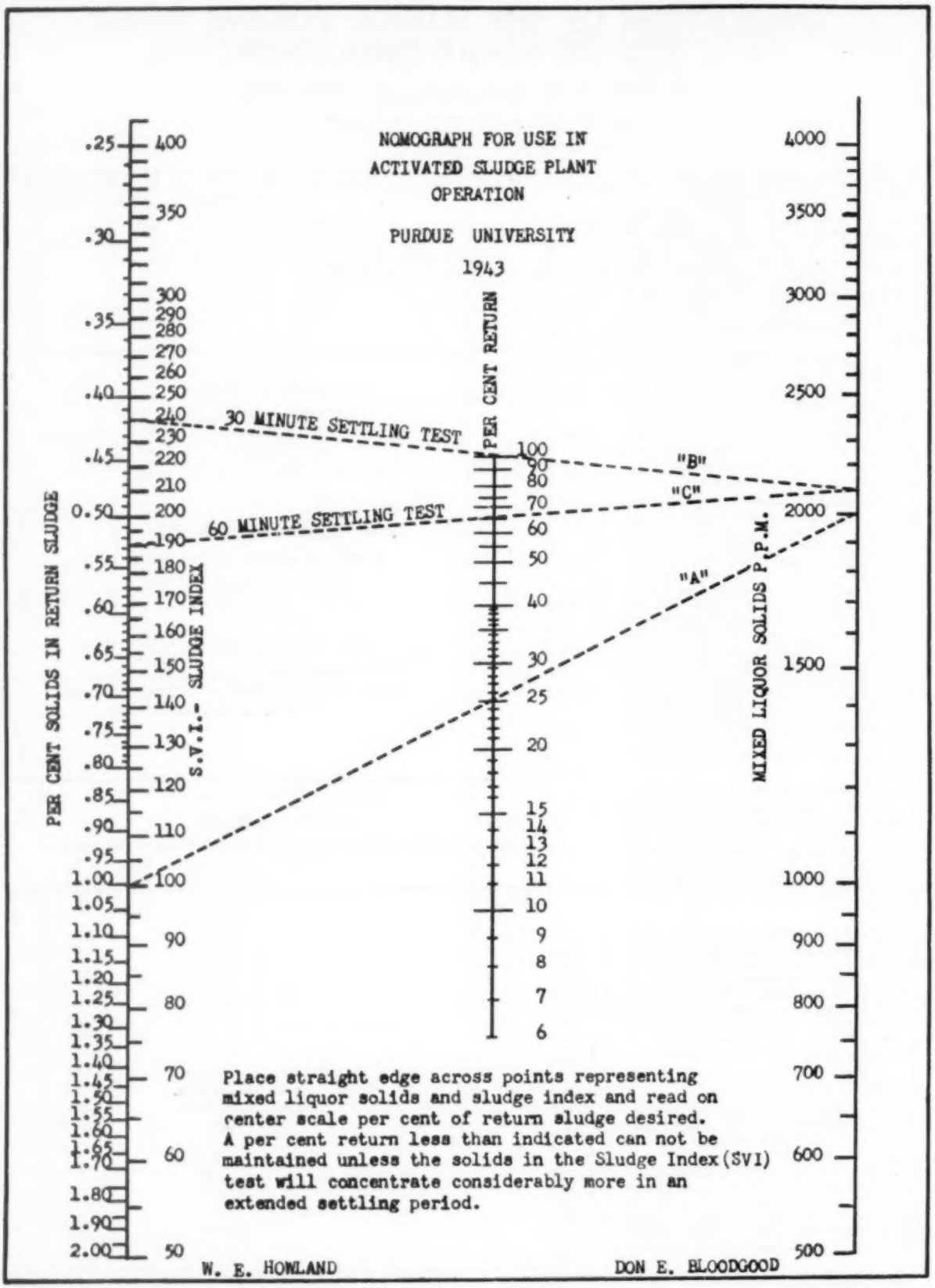

NOMOGRAPH FOR USE IN
ACTIVATED SLUDGE PLANT
OPERATION
PURDUE UNIVERSITY
1943
PER CENT SOLIDS IN RETURN SLUDGE
S.V.I.- SLUDGE INDEX
PER CENT RETURN
MIXED LIQUOR SOLIDS P.P.M.
30 MINUTE SETTLING TEST
60 MINUTE SETTLING TEST
"A"
"B"
"C"
Place straight edge across points representing mixed liquor solids and sludge index and read on center scale per cent of return sludge desired. A per cent return less than indicated can not be maintained unless the solids in the Sludge Index (SVI) test will concentrate considerably more in an extended settling period.
W. E. HOWLAND
DON E. BLOODGOOD

Fig. 3. Nomograph for Use in Activated Sludge Plant Operation.

A Useful Nomograph

Based on calculations with Formulae (2) and (3), a nomograph has been prepared (Fig. 3) which may be of assistance in activated sludge plant operation. Assuming the conditions as indicated by line "A," Fig. 3, with a mixed liquor solids concentration of 2000 ppm. and a sludge index of 100, it would be necessary to return 25 per cent by volume of return sludge of a concentration of 1.00 per cent. A higher per cent return could, of course, be maintained at an added return sludge pumping cost. On the other hand an attempt to return less than 25 per cent would mean holding the return sludge in the secondary tanks longer than seems advisable.

The assumed conditions as indicated by line "B," Fig. 3, with mixed liquor solids of 2100 ppm. and a sludge index of 240 (calculated on the regular 30-minute settling period) indicates the necessity of returning 100 per cent. Any amount of return less than 100 per cent would mean a rapid filling of the secondary settlers with sludge, unless the calculated sludge volume index at the end of a one hour settling test should be materially less than for a 30-min. test as illustrated by the line "C" in Fig. 3. In this case if a rate of sludge return of 65 per cent were maintained, the solids balance would be correct:

Comments:

1. If it is agreed that activated sludge should not be held in the secondary settling tanks longer than one hour it might be well to extend the period of settling of the sludge index test to one hour instead of the present thirty minutes.

2. The per cent of return sludge necessary for proper plant operation depends upon the mixed liquor solid concentration and upon the sludge index.

3. The nomograph presented is helpful in applying the sludge volume index test to the control of activated sludge plant operation.

The writer is indebted to Dr. W. F. Howland for his assistance in the construction of the nomograph presented.

E-Zee Bee-O-Dee

(From the DIGESTER of the Ill. Dept. of Health)

A SHORT, simple formula for the calculation of biochemical oxygen demand, developed by Professor H. M. Gifft of Cornell University, and published in the August, 1943, issue of *Water Works and Sewerage*, has been modified slightly by us [The Digester] for easier calculation.

The formula can be used for all types, strengths, and conditions of sewages, wastes, and polluted waters, with results identical to other accepted methods. It has the advantages of correcting automatically for the dilution water B.O.D. and of requiring only one dissolved oxygen test prior to incubation. In some cases even the D. O. Test may be estimated with sufficient accuracy. So—o—o, if you'd like to use something that makes your B.O.D work simple, try this method—it's easy.

Formula: $B.O.D. = (W - D) \times \frac{100}{P} + S - W$

W = D.O. in blank after incubation
D = D.O. in dilution after incubation
S = D.O. in sample before dilution
P = per cent of sample in dilution

Example 1: B.O.D OF RAW SEWAGE

Given: D.O. in blank after incubation = 8.0 = W
D.O. in dilution after incubation = 3.3 = D
D.O. in sample before dilution = 0.0 = S
per cent of sample in dilution = 2. = P

Then: $B.O.D. = (W - D) \times \frac{100}{P} + S - W$

Step 1 $(8.0 - 3.3) \times \frac{100}{2} + 0.0 - 8.0$

Step 2 $4.7 \times 50 + 0.0 - 8.0$

Step 3 $235 + 0.0 - 8.0 = 227$ ppm B.O.D (Ans.)

Example 2: B.O.D. OF PRIMARY EFFLUENT

Given: D.O. in blank after incubation = 8.4 = W
D.O. in dilution after incubation = 2.2 = D
D.O. in sample before dilution = 1.1 = S
per cent of sample in dilution = 5. = P

Then: $B.O.D. = (W - D) \times \frac{100}{P} + S - W$

Step 1: $(8.4 - 2.2) \times \frac{100}{5} + 1.1 - 8.4$

Step 2. $6.2 \times 20 + 1.1 - 8.4$

Step 3: $124 + 1.1 - 8.4 = 116.7 = ppm$ B.O.D. (Ans.)

Example 3: B.O.D. OF FINAL EFFLUENT

Given: D.O. in blank after incubation = 8.6 = W
D.O. in dilution after incubation = 2.6 = D
D.O. in sample before dilution = 6.4 = S
per cent of sample in dilution = 25. = P

Then $B.O.D. = (W - D) \times \frac{100}{P} + S - W$

Step 1 $(8.6 - 2.6) \times \frac{100}{25} + 6.4 - 8.6$

Step 2 $6.0 \times 4 + 6.4 - 8.6$

Step 3 $24 + 6.4 - 8.6 = 21.8 = ppm$ B.O.D. (Ans.)

EXPERIENCE IN THE OPERATION OF STANDARD TRICKLING FILTERS*

By DOUGLAS E. DREIER
Walker Process Equipment Co.

THIS article reviews practices in the operation of trickling filters of so-called "standard rate" design. It is largely based upon data and comments obtained from 35 superintendents, engineers, chemists and operators of 31 representative plants, through detailed questionnaires and by supplementary correspondence. The interest and complete cooperation of the following contributors are gratefully acknowledged:

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Harr, N. F., City Engineer, McPherson, Kan.
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Magennis, J. P., Chemist, Fort Dodge, Iowa.
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The data tabulated in Tables I and II indicate a wide variation in design, capacity and loading at the plants forming the basis for this summary. It will be observed that eighteen of the plants receive industrial wastes of consequence, some discussion of which will be included later.

Filter Loading

It is not the purpose of this discussion to enter the somewhat controversial subject of filter loading; however, a study of the data contributed reveals several plants operating, apparently with reasonably good results, at average loadings considerably in excess of commonly accepted design standards.

The summary of operation data from Fort Dodge, Iowa (Table III), is of interest as it relates to the operation of a two-stage standard trickling filter plant under heavy loading of packinghouse wastes. The sewage is first passed through a preareation tank 18 feet x 15 feet x 7.5 feet liquid depth. Air is applied continuously at 300 cfm. through a series of perforated pipes located near the tank bottom. (The grease floated is skimmed off and sold.) The flow is then subjected to 1.65 hr. of primary sedimentation followed by secondary treatment on two-stage trickling filters, each stage consisting of two 151-ft. diameter filters, 8 ft. deep, equipped with reaction rotary distributors. An intermediate settling tank is included in the design. The filter under-drains consist of slotted 6-in. tile, laid with open joints, radiating from the center of the filter to the periphery. The underdrain tile connect with ventilating stacks of the same diameter at 18-in. centers around the filter periphery.

The data in Table III are most interesting in demonstrating the ability of these trickling filters to perform under heavy overload. An average of 7.9 ppm. nitrates was contained in the effluent in spite of the heavy organic loading. The maximum monthly average B.O.D. reduction was 93.4 per cent, and the minimum was 78.9 per cent during the fiscal year reported. The maximum monthly average B.O.D. reduction occurred during July, the month which had the highest B.O.D. loading. That operation of the Fort Dodge plant under such a heavy loading was not without its difficulties will be observed in the latter discussion of operation problems.

Operation results at Decatur, Illinois, as reported by Hatfield for the month of August, 1944, and tabulated in Table IV, are also of interest. During that month the activated sludge portion of the plant was not operating, and although the trickling filters were loaded at 830 lbs. B.O.D. per acre-ft. per day, an average overall reduction of 87.3 per cent was obtained. The average B.O.D. removal by the filters and final clarifiers was 80.6 per cent. The Decatur trickling filters are of the fixed-

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Table I
GENERAL INFORMATION REGARDING CONTRIBUTING PLANTS

Plant	Connected Population	Type Sewers (1)	Average Flow (mgd.)	Avg. Prim. Sed. Period (hr.)	Type Prim. Tr. (2)	Avg. Final Sed. Period (hr.)	Type Final Tank (3)	Avg. 5-Day B.O.D. (ppm.) Raw Sewage	Prim. Eff.	Filter Eff.	Final Eff.	Rel. Stab. Eff. (days)	Industrial Wastes Tributary
Akron, Ohio	275,500	S & C	47.90	1.6	I	1.25	P	269	207	67	46	3	Synthetic rubber
Albermarle, N.C.	9,000	S	1.25	3.07	D	2.07	M	300	130	49	15	10	Textile dye
Aurora, Ill.	51,000	C	7.77	1.15	D	1.11	M	117	72	22	14	13	——
Bemidji, Minn.	6,000	S	0.45	1.5	D	1.5	M	——	——	——	——	——	——
Bloomington-Normal, Ill.	40,000	C	4.20	——	I	——	M	160	70	——	12	10	——
Bowling Green, Ohio	5,000	C	1.00	2.0	D	——	P	275	176	——	38	——	Tomato cannery
Clinton, Ill.	7,000	C	0.75	——	I	——	P	——	——	——	——	10	——
Corpus Christi, Texas	100,000	S	10.0	1.5	D	1.5	M	200	120	25	20	——	Seasonal Cannery, milk
Dayton, Ohio	325,000	S	54.4	1.7	I	1.6	M	227	137	46	33	——	Milk, packinghouse, paper
Decatur, Ill.	60,000	C	11.0	1.0	I & D	0.6	M	198	129	32	25	5	Corn products(6)
Des Moines, Iowa	160,000	C	15.3	3.5	D	2.75	M	200	——	——	41	5–12	Packinghouse
Plainfield, N.J.	60,000	S	4.25	1.0	D	1.0	M	629	320	26	13	10	——
Durham, N.C.	20,000	S	1.77	3.5	D	2.5	M	375	264	——	68	——	Textile dye
Elgin, Ill.	34,000	C	4.57	3.4	I & D	0.5	M	128	94	45	41	——	——
Fargo, N.D.	34,000	C	1.94	2.9	D	——	None	213	167	45	——	6	Gas plant, milk
Fort Dodge, Iowa	23,000	S	2.42	1.65	D	1.48	M	751	547	145(5)	105	——	Packinghouse (7)
Galesburg, Ill.	26,000	C	4.46	2.7	D	1.2	M	184	112	56	44	——	——
Griffin, Ga.	13,000	S	0.80	0.67	D	——	P	200	——	——	10	——	Laundry, textile
Huntington Beach, Calif.	3,000	S	0.30	2.0	D	——	None	——	——	——	——	——	——
Lebanon, Pa.	24,000	S	3.61	0.5	I	1.5	M	——	——	——	——	5	——
Litchfield, Ill.	6,000	C	0.52	3.0	D	3.0	M	360	220	16	5	10	Milk, oil
Madison, Wis.	35,000	S	4.82	2.25	I & D	3.44	M	248	139	50	33	13	Packinghouse
McPherson, Kan.	7,000	S	0.75	1.5	D	1.25	P	——	——	——	——	——	——
Oconomowoc, Wis.	4,600	S	1.13	2.4	D	2.1	M	143	99	15	8	10	Milk, pea cannery
Plymouth, Wis.	4,270	S	0.46	2.6	D	2.6	M	——	——	——	——	——	Milk, general cannery
Pontiac, Ill.	9,600	C	0.80	1.5	D	——	M	——	——	——	——	10	Milk
Pontiac, Mich.	70,000	S & C	7.70(4)	1.0	I	1.0	M	253	138	52	38	5	Cutting oil, grease
San Bernardino, Calif.	65,000	S	5.50	3.75	D	3.75	M	170	60	11	6	——	Chromic acid
Van Wert, Ohio	9,000	C	0.96	1.0	D	1.5	M	305	242	18	15	——	Cannery, milk, plating
Waynesboro, Pa.	8,500	S	0.88	——	D	——	M	236	——	——	31	10	——

(1) S—separate; C—combined.
(2) I—Imhoff tank; D—separate sludge digestion.
(3) P—plain hopper-bottom; M—mechanical.
(4) Part of flow treated by activated sludge.
(5) Effluent of second stage filters.
(6) Population equivalent 60,000-100,000.
(7) Population equivalent about 66,000.

nozzle design, 3 acres in area and 6 ft. deep. The high loading is largely due to starch wastes from a corn products plant.

Operation results at Akron, Ohio, for the year 1944, as reported by Schaetzle, are summarized in Table V. The Akron plant, containing 14 acres of fixed-nozzle filters 10 ft. deep, has been overloaded hydraulically and by solids for many years.

Loading data from many other plants could be added to the above as supporting evidence of the ability of standard trickling filters to provide treatment at higher loadings than they are commonly designed to accommodate. The use of slightly larger filter media to reduce ponding tendencies, adequate filter ventilation design, and the provision of recirculation facilities to assure continuous filter operation should permit considerably more optimistic design than has been practiced in the majority of designs. Provision of facilities for 1:1 recirculation at average flow can prove most helpful to the operator at times, and evidence of the general appreciation of this fact is found in the increased number of new designs including provision for recirculation. Loadings of 500 to 800 lb. B.O.D. per acre-foot do not appear unreasonably high, provided a fresh sewage is applied to the filters, with lower loadings reserved for situations where outlet conditions are critical or where local factors preclude projection of population equivalent loadings with sufficient assurance to warrant any optimism in design.

Filter Media

Table II includes information regarding the filter media at the various plants. It will be observed that experience with filter media has been generally satisfactory at the plants contributing to this summary, although some disintegration of media is reported.

Hatfield (Decatur, Ill.) reports that after 20 years service the filter stone has disintegrated from 1½ in. to about ¾ in., which has been partially responsible for ponding difficulties.

Johnson (Elgin, Ill.) reports that limestone media 1 to 2 in. in size placed in the Elgin filters in 1927 disintegrated sufficiently by 1939 to cause serious surface ponding. In 1941 the filter media at Elgin was removed and screened, and media retained on a 1½-in. screen was re-used. Twenty in. of 1¼ to 3-in. limestone was added, followed by a 14-in. top layer of 2¼ to 3½-in. granite, both of which passed the 20-cycle sodium sulfate soundness test. No disintegration of media has occurred at Elgin since 1941.

Magennis (Fort Dodge, Iowa) reports that limestone media which passed the 20-cycle sodium sulfate soundness test has not successfully withstood weathering. It has fractured badly with some of the pieces being quite small. Granite media in the other two Fort Dodge filters is still in good condition. Magennis calls attention to an important matter in the placing of filter media, suggesting that filter ponding has been most severe in the areas where media was dumped on the beds directly from the trucks, resulting in pockets of fine material. This again emphasizes the importance of care in the placing of filter media.

Care in selecting, grading and placing filter media is one of the most important factors affecting the operation of trickling filters. Unfortunate experiences have come from inadequate attention to this important item. It is thought highly advisable to specify that only a small percentage, never greater than 5 per cent, of a filter media can be smaller than the lower specified size. Fine material fills the voids in the larger media and, when much fine material is present, it is apt to segregate and form pockets during placing. It is important to re-handle media before placing it in the filter in order to avoid excessive quantities of fines and also to avoid segregation. Media should be re-handled with forks and placed with wheelbarrows or conveyors.

In general, experience with filter media sufficiently durable to withstand the 20-cycle sodium sulfate soundness test, in accordance with the sampling and laboratory procedures set forth in the *A.S.C.E. Manual of Engineering Practice No. 13*, has been satisfactory. Due to probable variation in quality of stone on various ledges of a quarry, and even at various places on the same ledge, it is important to exercise care that media is obtained from the same ledge area from which the soundness test sample is obtained. Reliance should not be placed in the results of an ancient soundness test submitted as evidence of general acceptability of the stone from a given quarry for use in trickling filters.

Table III

SUMMARY OF OPERATION DATA AT FORT DODGE, IOWA, APRIL 1, 1943 TO MARCH 31, 1944

	Avg.	Max.	Min.
Raw sewage flow, mgd	2.42	4.92	1.28
Filter loading:			
Flow, mgad. to each stage	3.02	6.15	1.60
Lb. B.O.D. per acre-ft. per day:			
First stage filters	1,741	3,078	615
Second stage filters	964		
B.O.D. data, ppm.:			
Raw sewage	751	1,327	264
Primary effluent	547	767	265
Average per cent removal	26.4		
First stage filter effluent	359	687	168
Intermediate clarifier effluent	304	559	115
Avg. per cent removal primary effluent to intermediate clarifier effluent	44.5		
Second stage filter effluent	145	394	34
Final effluent	105	288	25
Avg. per cent removal intermed. clarifier effluent to final effluent	67.6		
Avg. per cent removal by both stages filters and clarifiers	82.1		
Avg. overall B.O.D. reduction	86.6		
Nitrites in final effluent, ppm	0.8	4.25	0.10
Nitrates in final effluent, ppm	7.9	15.5	0.85
Outlet stream flow, cfs.	1,400	5,300	25

Table II

TRICKLING FILTER DATA

Plant	No. & Diam. (ft.) or Area (Acres)	Depth (ft.)	Type of Dosage	Type of Distrib. (1)	Filter Media: Type	Filter Media: Size (in.)	Filter Media: Weathering	Filter Media: Years in Service	Filter Media: Soundness Test Used (2)	Filter Loading: Lb. B.O.D. per Acre-Ft. Av.	Filter Loading: Lb. B.O.D. per Acre-Ft. Max.	Filter Loading: Av. Cu. Ft. Media per lb. B.O.D.	Effluent Nitrates Avg.	Effluent Nitrates Min.
Akron, Ohio	14 ac.	10	Siph.	N	Limestone	1 –2½	Mod.	17	A	590	703	74	1.32	0.16
Albermarle, N.C.	1-97	8	Cont.	R	Granite	1½–3	Mod.	7	None	—	—	—	—	—
Aurora, Ill.	3.74 ac.	6	Siph.	N	Limestone	1½–2	Sl.	16	B	192	867	227	6.35	2.8
Bemidji, Minn.	1-100	6	Siph.	R	Field Stone	2½–4	—	10	—	—	—	—	—	—
Bloomington-Normal, Ill.	2.5 Ac.	8	Siph.	N	Limestone	2	Sl.	18	—	188	313	232	—	—
Bowling Green, Ohio	4-100	7.5	Pumps	M	(3)	—	Mod.	10	A	—	—	—	—	—
Clinton, Ill.	1-140	7.5	Siph.	R	Limestone	1 –4¼	Sl.	10	A	—	—	—	—	—
Corpus Christi, Texas	4-160	6.5	Grav.	R	Limestone	1½–3	Sl.	8	None	—	—	—	—	—
Dayton, Ohio	20-165	7.5	Siph.	R	Slag	1½	Sl.	6	None	515	772	85	4.6	1.14
Decatur, Ill.	3.0 ac.	6	Siph.	N	Stone	1½	Bad	20	None	830	1,643	53	—	—
Des Moines, Iowa	12-152	7	Siph.	R	Gravel; stone	1½–3	Sl.	5	A	324	—	135	—	—
Plainfield, N.J.	1.78 ac.	6	Siph.	N	Trap rock	1½–2	None	29	—	1,080	—	40	—	—
Durham, N.C.	0.92 ac.	7	Siph.	N	Stone	1	None	17	None	556	—	78	—	—
Elgin, Ill.	1.54 ac.	8	Siph.	N	(4)	1½–3	(7)	3(7)	A	264	330	165	6.7	2.0
Fargo, N.D.	1.66 ac.	8	Siph.	N	Red granite	2 –2½	None	10	None	203	261	215	—	—
Fort Dodge, Iowa	4-151	8	Siph.	R	(5)	1½–2½	(8)	7	A	1,741(9)	3,078(9)	25	7.9	0.9
Galesburg, Ill.	1.06 ac.	6	Siph.	N	Limestone	1 –1½	Mod.	14	C	488	804	76	—	—
Griffin, Ga.	1-75; 1-105	6	Siph.	R	Stone	2½	—	8	—	—	—	—	—	—
Huntington Beach, Calif.	1-155	6	Siph.	N	Stone	1½–2½	Sl.	9	—	—	—	—	—	—
Lebanon, Pa.	1.3 ac.	6	Siph.	N	(6)	1½–3	(8)	17–32	None	600	1,475	73	—	—
Litchfield, Ill.	1-140	6	Pumps	M	Limestone	2½–4	Mod.	8	—	—	—	—	—	—
Madison, Wis.	2.0 ac.	10	Siph.	N	Dolomite	1 –1½	Sl.	17	—	279	434	174	7.0	3.2
McPherson, Kan.	1-90	8	Siph.	R	Stone	2	None	14	A	—	—	—	—	—
Oconomowoc, Wis.	2-140	7	Pumps	M	Gravel	2½–3	Sl.	8	—	—	—	—	—	—
Plymouth, Wis.	1-140	7	Pumps	R	—	—	—	—	—	—	—	—	—	—
Pontiac, Ill.	1-120	7	Pumps	M	Limestone	1½–2½	Sl.	9	—	—	—	—	—	—
Pontiac, Mich.	8-110	6	Siph.	R & M	—	1½–3	Mod.	25	—	136	—	320	—	—
San Bernardino, Calif.	2.46 ac.	7	Siph.	N	Gravel	1½–2½	None	17	—	175	—	250	—	—
Van Wert, Ohio	2-110	8	Siph.	R	Limestone	1 –2	None	10	A	—	—	—	—	—
Waynesboro, Pa.	1-145	6	Siph.	R	Limestone	1½–2½	Sl.	10	—	759	1,620	58	—	—

(1) N—fixed nozzles; R—reaction rotary dist.; M—motor-driven rotary dist.
(2) A—20-cycle Na_2SO_4; B—50-cycle freezing and thawing; C—Brard's test.
(3) Slag used for top 18 in., remainder limestone.
(4) Granite used for top 14 in., remainder limestone.
(5) Two filters limestone; two filters granite.
(6) Two filters limestone; one filter trap rock.
(7) Filter media replaced in 1941. No weathering since.
(8) Limestone weathering bad.
(9) First stage filters.

Table IV

SUMMARY OF OPERATION DATA FOR DECATUR, ILL., SANITARY DISTRICT, AUGUST, 1944

	Avg.	Max.	Min.
Raw sewage flow, mgd	13.8	15.1	11.4
Trickling filter loading, mgad	3.67	5.67	2.67
Lb. B.O.D. per acre-ft. per day	830	1,640	510
B.O.D. data, ppm.:			
Raw sewage	198	334	127
Primary effluent	129	267	88
Filter effluent	32	57	12
Final effluent	25	55	12
Per cent reduction, primary effluent to final effluent	80.6		
Per cent reduction, overall	87.3		
Nitrates in effluent, ppm.	1-2	5	0

Operation Problems

The questionnaires which were distributed to form a basis for this summary were most complete, and direct quotation will be used frequently in discussing the various trickling filter problems.

Ponding

A major problem in trickling filter operation has been that of ponding with resulting decrease in operating efficiency and frequently an increase in odor problems. About one-half of the operators contributing to this summary report ponding difficulties to varying degree.

Schaetzle reports that the Akron plant has been overloaded hydraulically and by solids for many years, which results in a ponding problem. He states:

"The plant was designed for 33 mgd. and 185 ppm. suspended solids in the raw sewage. The Imhoff tank effluent in 1944 contained 167 ppm. suspended solids with a flow of 47.9 mgd. The filters are protected by a 20-mesh vertical traveling screen, cleaned by water spray. Ponding is due to the overload. Filters pond in spots aggregating probably 10 per cent of the total area and in the top 6 to 8 in. We loosen the surface with a pick at ponding spots 2 to 3 times annually. Once every other year we harrow the entire 14 acres with a peg-tooth horse drawn harrow."

Allison (Corpus Christi, Texas) reports some ponding at the surface during the summer months due apparently to algal growth. Dragging a hooked bar over the surface is usually a sufficient remedy.

Mackin (Madison, Wis.) reports ponding at or slightly below the surface, apparently due to algal and other growths and accumulated solids joining together as a thin mat. This bonding occurs 2 or 3 times annually, affecting an area of 25 to 33 per cent of the filters. Mackin reports the use of chlorination in the summer for ponding control. The filters are cultivated in spring and fall with a horse drawn 2-wheeled farm cultivator, equipped with eight shovels, to a depth of about 8 in. A horse drawn peg-tooth harrow is then used to level the surface. Downes (Plainfield, N.J.) indicates that when small patches of ponded area occur, the surface of the filters is harrowed with a spike-tooth harrow and tractor. This is done about once annually.

Ponding at Decatur, Ill., was bad over about 5 per cent of the filter area during August, 1944, the month reported by Hatfield in answering the questionnaire. Rather bad ponding occurred at Decatur during the spring and early summer of 1945 due to a combination of heavy industrial wastes loading, undersize surface media, and silt accumulation in the filters after their flooding by the Sangamon River. Hatfield reports control of this ponding by systematic hosing of the entire filter area. Huffman (Dayton, Ohio) reports some ponding due to heavy load and some extra small particles of slag in the filter media. He states that ponding occurs near the surface and it is corrected by going over the ponded areas with picks. Working the ponded areas of the twenty 165-ft. diameter filters at Dayton requires 160 man-hours of labor.

Magennis (Fort Dodge, Iowa) reports ponding of the first stage filters to a serious degree, and to a lesser extent on the second stage filters at least twice a year. He continues:

"The first stage filters pond over about half their areas and the second stage filters over about a fourth of their areas. The clogging seems to extend the entire 8 ft. of their depths, especially on the areas where the rock was hauled out on the beds and dumped directly from the trucks. This deposited any fines, which may have been in the rock, all in one spot on each of the filter beds.

"For the last five years the average overload on the plant has been 78 per cent with an overload of 96 per cent last year. The maximum overload last year, figured on a monthly average, was 154 per cent. About 74 per cent of the total overload comes from a meat packing plant.

"In the spring and fall, when the ponding is worse, the beds are flushed with a fire hose carrying about 105 lb. pressure. This relieves the condition better than anything we have tried.

"Chlorine is used for odor control. It has been used in the past in an effort to relieve ponding, but to no avail even at dosages of 1,000 lb. per 24 hr. per filter for continuous periods of one week duration. The chlorine was applied to the filter influents."

The following is extracted from the 1943-44 annual report on the Fort Dodge plant:

"A clam shell was hired on November 27 to remove some rock from No. 1 filter down to the floor. It was desired to see the condition of the rock through its entire depth as this filter was badly ponded. This hole was dug on the west side of the filter near the periphery in the section that most readily ponds. It was found that every void was completely filled with humus sludge and slime. It seemed remarkable that any water could pass through at all. Some of the rock was quite small but this was not caused by disintegration but was probably due to the fact that all the rock in the filter was dumped from trucks on this one side and then spread out from there. These small rocks naturally remained where they were dumped.

"Samples of this sludge were carefully taken at 1-, 4- and 8-ft. (levels) and analyzed for grease, chloroform soluble on a dry basis, and organic material. That from the 1-ft. level showed 18.7 per cent grease and 63.8 per cent organic. That from the 4-ft. level showed 10.7 per cent grease and 67.6 per cent organic, while that from the 8-ft. level, or the floor of the filter, gave 22.3 per cent grease and 76.1 per cent organic. It seemed a little peculiar that the highest percentages should be found at the bottom of the filter but this may have been caused by the thorough flushings given a few months previous. It is evident that flushing with a fire hose and spotting of the distributor arms (stopping the distributors every foot or so and allowing them to remain stationary for thirty min. or more) will not correct this continuous problem of ponding, but only serves as a slight relief. It was found the following month that chlorine, applied at heavy dosages, would not correct this condition either. As long as the peak flows, B.O.D., and solids loadings remain high and the plant is not expanded or altered to meet these conditions it seems very unlikely that results of operation will improve very much."

Rehabilitation of the filters at Elgin, Ill., in 1941 eliminated surface ponding, however, Johnson reports that clogging of the beds at a depth of 8 to 16 in. has been in evidence during the late winter months of the past three years, Johnson states:

"It is my opinion that during cold weather, bacterial life in the top portion of the beds is retarded and insufficient to act properly upon the suspended solids which are retained, thereby causing an excessive film development which is responsible for the clogging. It appears to me that rotary distributors in place of the fixed-nozzle type of distribution would afford more uniform and continuous application which would be beneficial in maintaining the desired higher temperatures to induce bacterial action in the top portion of the beds.

"During the past winter chlorine was applied to the filters for one 10-hour night period at 3-week intervals in an effort to induce artificial sloughing. The chlorine dosage was sufficient to maintain 3.2 to 5 ppm. residual at the nozzles. Increased solids unloading occurred after each application of chlorine, and nitrate nitrogen analyses of filter effluent indicated the beds apparently were not clogged to the extent of previous years; however, the spring unloading was as heavy and enduring as in 1943 and 1944. The unloading extends from April to June, and the filters do not recover to function properly until July. Low overall treatment plant efficiencies reflect to this extensive sloughing period and inadequate final sedimentation capacity as now provided."

Hunt (Galesburg, Ill., Sanitary District) states:

"Ponding occurs during the late winter

Table V

SUMMARY OF OPERATION DATA FOR AKRON, OHIO, 1944

	Avg.	Max.	Min.
Raw sewage flow, mgd	47.9	94.0	27.2
Filter loading, mgad	3.5		
Lb. B.O.D. per acre-ft. per day	590	703	482
B.O.D. date, ppm.*:			
Raw sewage	269	310	222
Primary effluent	207	241	187
Filter effluent	67	93	41
Final effluent	46	78	27
Per cent reduction, primary effluent to final effluent	77.8	68.9**	85.6**
Per cent overall B.O.D. reduction	82.9	78.8**	87.8**
Nitrates in final effluent, ppm.*	1.32	2.56	0.16
Outlet stream flow, cfs. (1931-35)	273		25

*Maximum and minimum data are monthly averages.
**Correspond to B.O.D. data above.

and early spring. The area covered by ponding has on some occasions covered as much as one-half the filter area. Clogging seems to be in the top six inches of stone. The cause appears to be small voids between the stone, and rather heavy B.O.D. loading. As soon as cold weather appears the filter effluent becomes noticeably turbid.

"Chlorine has been used to control ponding with fair success, but has not been used the past two years. (Hand picking has also been done.) Chlorine is applied to the primary effluent. Settled sewage of average strength has a high chlorine demand and, therefore, night or protracted storm flows are chlorinated, an attempt being made to maintain a residual of 2 to 5 ppm. at the surface of the stone."

Spiess (Litchfield, Ill.) reports that ponding used to be a problem during the winter months, presumably due to milk wastes. Spiess used a road scarifier to give temporary relief. During the past few years chlorination of settled sewage has been practiced from April to October, resulting in a "clean" filter to enter the winter period, thus eliminating difficulty from ponding.

Beamesderfer (Lebanon, Pa.) reports that ponding of filters occurred about four times during each of the past winters, and about 50 per cent of the filter area was clogged at the surface. He states:

"The cause was carelessness in skimming and squeegeeing the Imhoff tanks, thereby sending too much settleable solids over the weirs, overloading the filters. After four years of educating the operators, I proved to them that the best method of working the Imhoff tank is to shut off the tank and allow the disturbed settleable solids at the slot line to settle before putting the tank into service. This winter is the first winter in the history of the plant that the filters did not clog."

Lantenbach (Plymouth, Wis.) and Doyle and Dubay (Pontiac, Mich.) indicate that ponding is effectively remedied by going over the ponded area with a crowbar. Slight ponding at Clinton, Ill., is corrected by use of a pick, according to Corrington. Resting the filter is reported by Shick (Van Wert, Ohio) and Craig (Pontiac, Ill.) as the best remedy they have found for ponding.

The above experiences with ponding just about run the gauntlet of causes and remedies. It is axiomatic that an operator who experiences ponding difficulties should study his plant and the sewage to determine the contributing causes, and then take whatever steps are possible or practical to eliminate or control the causes so that it will be unnecessary to apply remedies. This advice is simple to give, but unfortunately its execution is not always readily attained. The author might add here that chlorination has proved very effective at several Illinois plants where filters were badly ponded due to heavy overload from milk wastes. Unless ponding was very deep, chlorine dosages of about 10 lb. per 1,000 sq. ft. of filter proved effective. At Marissa, Ill., where the filter was completely ponded due to milk wastes, the ponding was brought under control by sprinkling HTH on the filter at the rate of about 8 lb. available chlorine per 1,000 sq. ft. After a couple of days the ponding was under control and the stability of the plant effluent increased from less than 1 day to 10 days, within about one week. Steps were then taken looking toward better control of wastes at the milk plant.

Occasional moderate doses of chlorine have been found of value at some plants in controlling excessive surface growths, and many plants have experienced better operation when a small continuous or semi-continuous chlorine dosage is applied to the settled sewage. This tends to keep the filter open and puts it in better condition to enter the winter period when more solids accumulate in the filter.

Nozzle Clogging

Every plant operator does a certain amount of maintenance in keeping filter nozzles clean. In a small plant the time consumed in nozzle cleaning usually is not great; in the large plants, however, this is usually an item of some magnitude.

Schaetzle (Akron, Ohio) reports that it requires 48 man-hours a week to keep nozzles clean and do the necessary weekly flushing of distribution laterals on 14 acres of filters. He reports that it would require two or three times that amount of work to keep nozzles clean if a 20-mesh, water spray cleaned, vertical traveling screen were not in use on the settled sewage.

A number of other plants have settled sewage screens of one kind or another. Green (Bemidji, Minn.) has installed a 30-in. long conical screen of ¼-in. mesh in the primary effluent outlet. This screen is cleaned daily and no trouble with nozzle clogging is experienced. Barnes (Bowling Green, Ohio) reports that a ⅜-in. mesh settled sewage screen, while effective, does not entirely eliminate nozzle clogging. A 3-mesh screen, cleaned weekly, saves Corrington (Clinton, Ill.) a lot of work cleaning nozzles. Hatfield (Decatur, Ill.) uses a ¼-in. mesh settled sewage screen effectively, but he reports it causes some grease separation on the surface of the dosing tanks. Hatfield designed a non-clog nozzle which greatly reduced his cleaning problem, as did Beamesderfer (Lebanon, Pa.). Pinney (Fargo, N. Dak.) uses a 5/16-in. mesh screen ahead of the dosing tank, and nozzle cleaning requires 1¼ man-hours daily. Simonton (Griffin, Ga.) reports good results with a ¼-in. mesh screen. Craig (Pontiac, Ill.) finds a ¾-in. mesh screen most satisfactory. Shick (Van Wert, Ohio) reports a ¼-in. mesh screen just about eliminates nozzle clogging if properly handled. Spiess (Litchfield, Ill.) is a "dissenter" regarding the value of a settled sewage screen. He discarded a ⅜-in. mesh screen because he experienced more trouble cleaning it than orifices. Sperry (Aurora, Ill.) sums up the matter by commenting that he would like to install a settled sewage screen, but has not been able to find a way or place where such a screen could be used.

Huffman (Dayton, Ohio) reports that a 50 to 60 per cent stoppage of nozzles occurs when the direction of flow is changed in the Imhoff tanks. He explains that the suspended solids load is considerably greater than the design capacity of the Imhoff tanks, the plant hydraulics are rather "tricky" since the secondary units were added in 1938, and plant personnel is limited, all of which are involved in this problem. He adds:

"Stop logs are provided to keep scum and other material from the idle effluent channel but on peak flows it is very easy to raise the water level sufficiently to allow material to pass over the scum boards, consequently during a four-week period considerable scum collects in the idle effluent channel and this passes on to the filters 'with a bang' when the direction of flow is changed."

In summary, it can be stated that nozzle clogging is a universal problem to a widely varying degree, and the use of settled sewage screens generally is reported to be of considerable assistance in its control. Most operators contributing to this summary indicated that nozzle cleaning is a daily chore.

General Cleaning

From the questionnaire returns it appears that the periods between cleaning of dosing tanks and distribution systems vary from about once weekly to about once annually. Green (Bemidji, Minn.) reports distribution arms are flushed daily, Alikonis (Bloomington-Normal, Ill.) reports a weekly cleaning schedule, while Huffman (Dayton) and Winfrey (Des Moines) indicate the filter distribution system at their plants has never been flushed.

Distributor arms on rotary distributors are normally flushed by merely opening the gates on the ends of the arms one at a time, but the problem is somewhat different at Fort Dodge, Iowa, as described by Magennis in his 1943-44 Annual Report:

"On June 3 the influent lines and distributor arms of filters No. 1 and No. 2 were cleaned with a six-inch auger on sewer rods. A considerable amount of accumulated grease was removed which had been retarding the flow so much that it backed up into the primary clarifiers and overflowed the weirs, permitting large quantities of grease and other floating material to flow out on the first stage filter beds which were already badly ponded. Large pieces of grease were also removed from the center columns of all four distributors. This remedied the condition."

Johnson (Elgin, Ill.) reports:

"Our procedure for flushing out the filter distribution system, once weekly, is to first remove the end nozzle of each lateral. The two main header drain valves are then partially opened and left open until each dosing tank has discharged three or four times. Thus, the distribution system is largely drained before each siphon discharges, allowing air to be entrained which provides the effective flushing action."

Hatfield (Decatur) flushes the distribution system daily, also by opening the drain valve, allowing the system to partially fill with air, then closing the drain valve and obtaining good flushing action when the siphon discharges. From Hatfield's vivid description, this method of flushing the distribution system really gets results.

While most operators reported that underdrains are not flushed out, Beamesderfer (Lebanon, Pa.) and Har (McPherson, Kan.) indicated that the underdrains are flushed out twice yearly with a high pressure hose. Shick (Van Wert, Ohio) flushes out underdrains on alternate years. Corrington (Clinton, Ill.) reports the underdrains were flushed out during the first year of operation due to rock dust accumulations. Mackin (Madison, Wis.) flushes underdrains annually by attaching a self-propelling nozzle to a 1½-in. hose.

Psychoda Flies

Probably no nuisance problem in sewage treatment has been wider discussed than that of control of the insect *Psychoda alternata*. Of the plants contributing to this summary, 21 have had or still have a filter fly problem. At the remaining plants no problem of magnitude was reported.

The adult *P. alternata* lays its eggs in the filter growths. The larvae hatch in about 48 hrs. and develops into adult flies by the 15th day. The larvae are ravenous eaters, and utilize the growth on the filter media as their source of food. In a heavily infested filter they may almost denude the film from the surface media; however, this is not too common. There is considerable thought that the larvae are beneficial in

helping keep a filter loose and open, which is reasonable considering their food source and their huge number. The unfortunate fact is that the larvae will reach adulthood, and during filter rest periods the flies may leave a filter in great numbers.

The most common method of filter fly control is that of flooding the filters every 7 to 14 days for a period of 24 to 36 hrs. This drowns the larvae and may also flush out some eggs. This frequency of flooding is within the development cycle of the fly, which is necessary to achieve results. Nine of the contributors to this summary use flooding for fly control with results varying from good control to minor benefit. Moore (Albemarle, N.C.) indicates that some odor is present after 36 hrs. of flooding. Spiess (Litchfield, Ill.) states flooding every ten days helps a lot, but he does not consider it the answer due to the necessity of his discharging 0.5 mg. of primary effluent to the outlet while the bed is flooded. He also indicates that snails and worms float to the surface and result in a bad odor nuisance, which is now effectively controlled by chlorination of the settled sewage.

Chlorination is also utilized in attempting filter fly control, again with reports of both successful and mediocre results. Magennis (Fort Dodge) reports that chlorination has been tried for filter fly control with no particular success. Mackin (Madison) reports that some fly control seems to be realized by chlorine dosage of 6 to 15 ppm. to the settled sewage, which is applied primarily for odor control. He describes chlorination as moderately successfully for filter fly control at Madison.

Allison (Corpus Christi, Texas) reports successful use of chlorination combined with recirculation in controlling flies, odors, and slime growth. His interesting comments follow:

"When 1,000 gpm. recirculation was started, the prechlorination rate was 850 lb. per day. Prechlorination (ahead of primary tanks) at a 25 per cent hieher rate gave very little odor control. Five hundred pounds per day (approximately 6 ppm.) postchlorination (following filters) gave excellent results in stopping complaints from odors, eliminated 3½ hours of daily cleaning of final clarifiers, and stopped *Psychoda* fly nuisance. Railroad engine shops alongside the plant were contemplating moving away because of the flies interfering with workmen. No complaints have been received since this control was started.

"We can kill larvae by increasing chlorine residual during the night recirculation. Complete control is obtained by returning to the primary clarifiers 1,000 gpm. from the bottom of the secondary clarifiers. This carries a chlorine residual during minimum flow at night and carries sufficient residual to the filters to kill fly larvae.

"Continuous dosage (application of sewage) keeps flies at a minimum. Shut off dosage on a sunny day and within two hours you can note the increase in flies. On a warm sunny day shut a well-coated filter down and you can observe the fly larvae clean the surface film at the rate of 4 square inches in 30 minutes, and double their size. Continuous dosage seems to wash the larvae through the filter just previous to their forming into the adult fly."

Hager (San Bernardino, Calif) reports a fly problem from January to May. He reports that the insects are kept at a minimum by weekly dosage of the filter influent with 300 lb. of chlorine over an 8-hr. period in the early morning hours when the flow is low. This gives a residual of 0.10 ppm. at the dosing tanks.

Downes (Plainfield, N.J.) reports *Psychoda* have not been a problem since continuous flow over the entire filter area has been maintained by pumping back filter effluent to maintain a 7 mgd. flow rate to the filters (3.9 mgad.). He reports no adult flies on the wing as long as the flow continues, but reminds that they are under the surface stone and emerge if the flow is stopped for even a few minutes. This brings out the advisability of adjusting the distribution, if possible, to avoid dry areas or areas only slightly wetted, which give the flies their opportunity to take wing.

Regarding the possible effectiveness of the small water springtail, *Achorutes viaticus*, in controlling filter flies, replies ranged from completely negative to one positive. As most operators are aware, the *Achorutes* is a small, blue-black, wingless insect which can jump several inches by means of its so-called "springtail." Some filters have been naturally infested with the *Achorutes*, while a considerable number of filters have been seeded with them by transferring media from an infested filter. Not all efforts at transfer have been successful. Downes (Plainfield, N.J.) advises that the *Achorutes* gave no assistance in *Psychoda* fly control; conversely, Corrington (Clinton, Ill.) reports that since seeding the filter with springtails, less and less trouble with filter flies has been experienced until they are now present only in small numbers. Johnson (Elgin) reports *Psychoda* flies were a nuisance, and in 1931 *Achorutes* were transplanted from Madison, Wis. In two years, seemingly with the increase in numbers of springtails, the fly nuisance abated. The flies are now present in greatly reduced numbers and they remain in the filter area. Johnson cautions that he is not sure whether the springtails are entirely responsible or if other conditions were partially responsible for the decrease in fly population. The *Achorutes* survived the filter rehabilitation at Elgin in 1941. Mackin (Madison) reports that the *Achorutes* are occasionally furnished to others by request. He indicates that they may be of some benefit, but that he does not feel their benefit is substantial.

Harr (McPherson, Kan.) indicates he treats the filter with creosote periodically and burns flies with a kerosene torch in the mornings. He did not indicate the effectiveness of these practices. Beamesderfer (Lebanon, Pa.) reports that the rough stone walls of the filters are sprayed with a 3:1 mixture of crankcase oil and kerosene attracting the flies which come into contact with the oil, stick fast and die. Then, he reports, the filters are by-passed for 4 to 5 days to dry out the film on the beds, which is followed by increasing the rate of sewage application to flush out the dried film and unload the beds. Beamesderfer reports that these procedures keep filter flies under control, but he did not indicate the frequency of this control measure. Outlet stream requirements at most plants would not allow any such period of by-passing secondary treatment.

Other chemicals, such as pyrethrum and ammonia, have been used in attempts at filter fly control, usually with indifferent results. Published results of plant scale experimentation with the new insecticide, DDT, in the control of *Psychoda* flies are awaited with interest. The author has had the pleasure of reviewing one interesting paper based on an entomological study of *Psychoda* larvae and flies as affected by DDT, and it is hoped that this and other worth-while papers on the subject will be made available soon. (See *Sew. Wks. Jour.* 18. 1 (March, 1946) pages 181 and 208). Alikonis (Bloomington-Normal, Ill.) has done considerable work with DDT, and he indicated at the 1945 Illinois Sewage Works Operators' Conference that he has found DDT very helpful in controlling the adult flies.

Odors

Odors are usually not a problem if filters are operating well and receive fresh sewage; if a septic sewage is applied, however, a considerable nuisance may result from the release of odorous gases as the sewage is sprayed onto the filters. Needless to say, all odors at a plant are not necessarily released at the filters.

Of the plants contributing to this review, many experience odor problems. Schaetzle (Akron) reports they have had 25 to 30 damage suits because of odors and gnats and have lost all that came to trial. He indicates that cleanliness is the only precaution they can take against odors as no provisions are made for the use of chlorine. He also indicates that he is obliged to lagoon practically all sludge, most of it in an undigested state, which "does not reduce odor complaints."

Eleven of the contributors reported use of chlorination for odor control. Both pre- and post-chlorination are practiced at Bowling Green, Ohio, by Barnes. Odor control is very important at Bowling Green since the plant is located along a main thoroughfare and close to a university and airport. Barnes indicates that 150 lb. of chlorine are used daily. Allison's practice at Corpus Christi of recirculation and chlorination of filter effluent is described in the discussion of *Psychoda* fly control. Allison indicates the chlorine residual in the recirculated flow at 6:00 a.m. is about 1.5 ppm. The Corpus Christi plant is 3,000 feet from the center of town, and no odor complaints have been received since practicing this method of control. Downes (Plainfield, N.J.) chlorinates the raw sewage for odor control, as does Mattson (Oconomowoc, Wis.). The latter applies chlorine at 4 to 7 ppm. when pea canning is in progress. Lantenbach (Plymouth, Wis.) applies 20 lbs. of chlorine daily to the raw sewage during the hot months when the local cannery is discharging chemically pretreated wastes to the municipal sewers. Shick (Van Wert, Ohio) applies 60 lb. chlorine per day from June to September, to the raw sewage at the lift station one mile from the plant, to prevent the sewage from becoming septic.

Mackin (Madison) adds 6 to 15 ppm. chlorine to the settled sewage for odor control. Beamesderfer (Lebanon, Pa.) applies 2 ppm. chlorine to the Imhoff tank effluent for odor control. Also, dissolved oxygen tests are made on the raw sewage and when no D.O. is present, recirculation is started at a 0.60-mgd. rate to the raw sewage. Beamesderfer reports this practice as very effective in controlling odors. Magennis (Fort Dodge) adds about 16 ppm. of chlorine at the dosing tanks for odor control. Fort Dodge is another municipality which has paid rather heavily for settlements, judgments, and legal services in lawsuits and claims due to alleged odors. Magennis states:

"Odors are not nearly the problem they used to be due to the fact that the packing company waste is now being received in a much fresher state than it was a few years ago when some of the material was held by them for as long as 24 hours before it was dumped, which usually occurred at night during the light flows. Since the construction of a main catch basin with continuous grease skimming equipment, the material is fed to the sewers about as

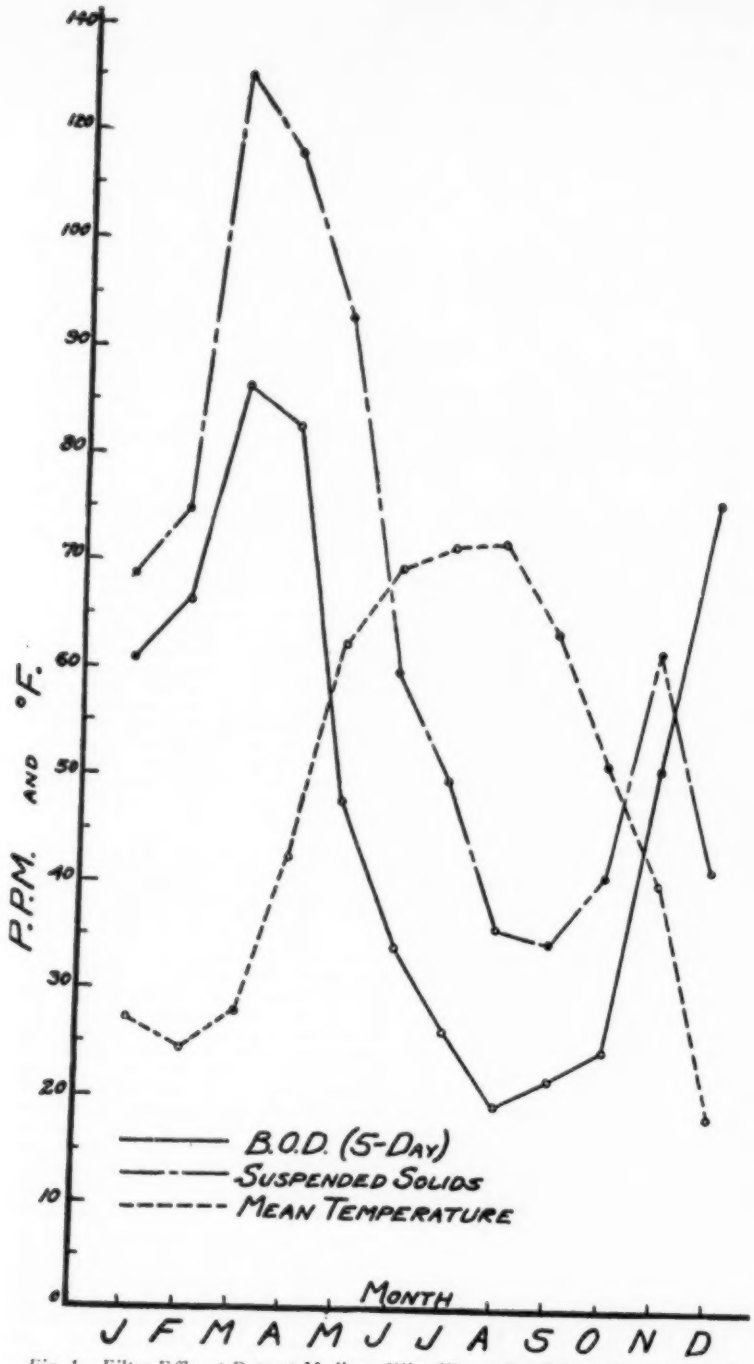

Fig. 1.—Filter Effluent Data at Madison, Wis., Illustrating Effect of Temperature Variation (1944 Monthly Averages).

fast as it is produced. This has alleviated much of our odor trouble. We do, however, at times have a characteristic packinghouse odor which comes off our preaeration tank which is used for grease removal. The only other odor we have comes from the filters and is more or less a musty odor. Both of these odors can be controlled by the use of liquid chlorine."

Recirculation of final effluent is also used as an odor control measure at Fort Dodge. When the last raw sewage pump stops, a 1,000-gpm. recirculation pump automatically starts, which helps reduce odors emanating from idle filters, particularly during the night. This recirculation usually takes place between 1:00 and 6:00 a.m., during which time the recirculation pump operates approximately 50 per cent of the time.

Hager (San Bernardino, Calif.) reports that preaeration eliminates all hydrogen sulfide odors at his plant. Preaeration, if in sufficient amount, can prove very helpful in odor control in addition to its substantial assistance to the efficiency of primary sedimentation units.

Sperry (Aurora) indicates that odors are generally not a problem, as the hydrogen sulfide content of the settled sewage is consistently below 1 ppm., which is not enough to cause complaint. He does indicate, however, that many times during the summer a noticeable taint of hydrogen sulfide can be observed across the river from the plant in the quiet of the evening. This is still a function of the weather in the typical way, *i.e.*, the odors tend to stratify and follow ravines on quiet, cool evenings.

With the exception of Shick's practice at Van Wert, none of the operators reported chlorination up-sewer from the plant. Chlorination ahead of long force mains is definitely helpful, both for odor control and to permit delivery to the plant of a sewage which is not rendered much more difficult to treat due to its septicity. Flushing flat, sluggish sewers periodically in warm weather also is helpful in delivering a fresher sewage to the plant for treatment, at the same time assisting in odor control.

Unloading

In general, solids tend to accumulate in low rate filters, particularly during the winter months when biological activity is reduced. These solids slough off periodically, usually in the spring when biological activity increases, but at some plants in both spring and fall. The sloughing period varies considerably in length and intensity at the plants covered in this summary, from a few days at Des Moines to as long as three months at Elgin. Several operators reported more or less continuous unloading. Downes reports continuous unloading at the Plainfield filters since the recirculation practice was started, and Hatfield (Decatur) also reports more or less continuous unloading at a plant where no recirculation is practiced. Allison (Corpus Christi) reports filter unloading for four or five days after a temperature drop to 35° or 40°F.

The filter unloading problem assumes greater proportions at Elgin, Ill., where Johnson reports unloading continues from April to June with the humus load during unloading from 300 to 800 per cent of normal. Sludge storage facilities are taxed during the sloughing period and the filters do not recover to function normally until July. A sludge lagoon helps to overcome the sludge storage element of this problem at Elgin.

At Galesburg, Ill., Hunt reports 35 to 50 per cent more humus load during the two months filter unloading period. At Galesburg, with digesters loaded to capacity, this results in excessive gas production with the gassing rate sufficient to cause a thin digested sludge. Mackin (Madison) reports 3 to 6 weeks unloading in the spring and 2 to 3 weeks in the fall, with a humus load of 300 per cent above average resulting in the overloading of digesters.

Winter Operation

Less than half of the plants included in this summary reported any particular difficulty in winter operation; the majority of plants, however, do take some common sense precautions to avoid damage to equipment or interruption of operation.

An almost universal procedure at plants having intermittent dosage, where freezing temperatures are encountered, is that of partially opening drain valves in the laterals of fixed nozzle systems to lower the sewage level in the vertical risers between doses, and thus reduce opportunity for freezing in the risers. With rotary distributors, the drain valve in the distributor base is usually opened slightly to prevent

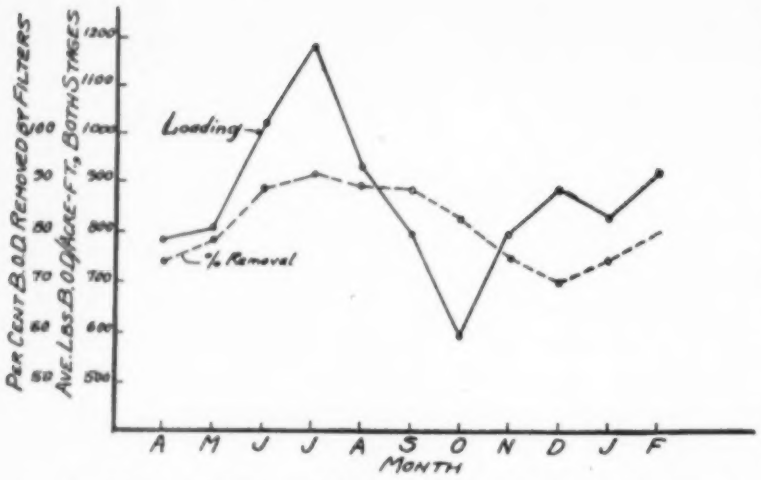

Fig. 2.—Effect of Temperature Variation on Efficiency of Two-Stage Filters at Fort Dodge, Iowa (1943-1944 Monthly Averages).

freezing in the distributor arms.

In severe weather a rotary distributor may be interfered with by ice building up in a ring (or part of a ring) around the filter wall, or in circular ridges on the bed. A ¼-in. hole drilled in the end gate of the distributor arms to direct a flow of sewage against the wall has been found helpful at some plants in reducing ice formation around the filter wall. (Tap the hole so a plug can be inserted during warm weather.) Formation of ice around the filter walls is a problem at Plymouth, Wis., and Lantenbach reports that the 4-ft. arm extensions on the distributor are removed and ice is chopped when necessary to keep the distributor free to operate. Corrington (Clinton, Ill.) corks the last four orifices on the distributor arms to help control ice formation around the outside wall, and chops away this ice formation when necessary. During continued sub-zero weather Corrington blocks the distributor in one position. Barnes (Bowling Green, Ohio) reports that ice builds up sufficiently in extreme cold weather to stop the distributor arms, which are a minimum of 9 in. above the media. During extreme cold weather Barnes by-passes the filters, and prevents the final tanks from freezing by passing the flow through them by way of the handhole plates in bases of the rotary distributors.

Johnson (Elgin) reports:

"Since rehabilitation of the filters (in 1941) no ice formations have developed. In previous years, with weather comparable to the cold winter just experienced (1944), ice would form to heights of 2 to 3 feet. Large surface stone used in repairing the beds is considered the main contributing factor in correcting this condition.

"To minimize freezing in winter operation, dosing tanks are covered with planking, siphon piping on the exterior of the dosing tanks is housed and insulated with straw, nozzles are inspected twice daily, and colored warning lights connected to the dosing tank counters are provided so that the night watchman can observe from the office building that the filters are operating in their proper sequence."

Magennis (Fort Dodge) reports that packinghouse wastes raise the temperature of the raw sewage so that freezing is no problem at the first stage filters, and is of consequence at the second stage filters only when the air temperature is zero or lower. Magennis further reports that the most persistent freezing on the filters occurs at the periphery of the beds over the vertical ventilation stacks. The wall and ventilation stacks extend about 1 ft. above the media and this serves as a "snow fence." The nozzle spray coats this snow and eventually forms ice which keeps building up until it must be removed with a pick. To minimize this difficulty, the outside orifice on each distributor arm is plugged so the spray will not reach the wall. This has solved that particular problem. During prolonged cold weather, the spreader plates over the distributor orifices are lifted, concentrating the flow from each orifice in a confined area around the filter. Magennis reports this practice has aided a great deal in maintaining filter operation during extreme cold weather.

Winfrey (Des Moines) and Spiess (Litchfield, Ill.) report use of recirculation to minimize freezing at the filters by cutting down the dosing cycle during low flow periods. Winfrey also cracks open the end gates of the distributor arms.

Green (Bemidji, Minn.) reports no ice problems (although his city frequently reports the coldest temperature in the nation), due to the housing of the filter. Pinney reports no iice problem at the Fargo, N.D., filters for the same reason (Figures 4 and 5). It goes without saying that Hager (San Bernardino, Calif.) and Clark (Huntington Beach, Calif.) have no winter operation problems related to ice formation!

Unusual Problems

An unusual problem is reported by Magennis at Fort Dodge, Iowa. He describes it as follows:

"For the last fiscal year an average of 6.8 cu. ft. of grit was removed from the detritor daily. Three-fourths or more of this grit was composed of tiny snail shells which were pumped with the humus sludge from the intermediate and final clarifiers. These snail shells came from the filters. Large quantities of them pass through the detritor, settle in the primary clarifiers, and are pumped with the raw sludge to the digesters. In 1942, after four years of operation, two of our digesters were drained for inspection. In the bottoms under the discharge openings into the digesters were found piles of sand, grit and snail shells. These piles sloped down on each side and toward the sump in the center of the floor. This collection of material covered the lower heating coils nearly half way around each digester. This accumulation reduced the digester capacities about 10 per cent. Incidentally, the removal of this material was a slow and tedious process, taking over a month for completion. It was accomplished by the use of the positive displacement sludge pumps and a fire hose. Two or three complete stoppages of the sludge line were encountered before the job was completed."

Spiess (Litchfield, Ill.) reports a difficult scum problem in the digester, with the scum layer accumulating to depths of 6 to 8 ft., which he attributes in part to the large quantities of snail shells flushed from the filter and pumped to the digester with the humus sludge.

An unusual problem at Corpus Christi, Texas, is that of galvanic and other corrosion of metallic equipment due to the high chloride content of the sewage, which results from infiltration of salt-bearing ground waters. Allison reports that the chloride concentration reaches 3,200 ppm. during the night flow, but this causes no operational difficulty other than the corrosion.

Temperature Effect

Temperature is an important factor in the functioning of any biological process, and the trickling filter is no exception. If a filter receives a fresh sewage within its loading capacity, it normally produces its best effluent during the warmer months. This is borne out by the questionnaires returned, and was particularly commented upon by thirteen operators. Several operators indicated, however, that they could not observe any decrease in filter efficiency during the winter months.

Sperry (Aurora), Alikonis (Bloomington-Normal), and Craig (Pontiac, Ill.) all note no particular decrease in efficiency during winter operation. Conversely, a decided drop in efficiency is reported at Akron, Ohio, Albemarle, N.C., Bowling Green, Ohio, Decatur, Ill., Dayton, Ohio, Galesburg, Ill., Griffin, Ga., and Pontiac, Mich. Downes (Plainfield) reports that the effluent stability drops from 10 days in summer to 4 to 5 days during February, March and early April. At Lebanon, Pa., Beamesderfer reports that the effluent stability drops to 50 per cent during the winter. The cold can penetrate the Lebanon filters very deeply as the filter walls are constructed of large stone laid with open joints. Hager (San Bernardino) reports a decrease in filter efficiency when the temperature dropped during the winter of 1944.

Mackin (Madison, Wis.) reports a decided drop in filter efficiency during the winter months, and experiences at Madison are graphically illustrated in Fig. 1, which shows B.O.D. and suspended solids in the filter effluent by monthly averages, and mean monthly air temperatures, for the year 1944.

Magennis (Fort Dodge, Iowa) reports a 25 to 30 per cent drop in filter efficiency during the winter months. Fig. 2 was plotted from data contained in the Fort Dodge 1943-44 annual report, the loadings indicated being based on the monthly average pounds of settled sewage B.O.D. per acre-foot of volume of both stages of filters. The final effluent B.O.D. was 44 ppm. in July when the overall loading was 1,180 lb. per acre-foot, and the effluent B.O.D. was 188 ppm. in December when the overall loading was 890 lbs. per acre-foot. The per cent B.O.D. removals indicated in Fig. 2 include that removed by filters and secondary clarifiers.

Recirculation

Recirculation has received greatly increased attention in recent years with the development of high-capacity filters. Its application has not been restricted to high-capacity filters, however, as quite a number of plants of standard rate design have applied recirculation with good effects for a number of years. Recirculation applied to standard rate filters has resulted in their ability to handle considerably higher loadings without ponding, has increased efficiency of existing plants, and has assisted greatly in the control of odors and *Psychoda* flies.

Recirculation is applied in a number of combinations. Filter effluent, final tank underflow, or final effluent may be recirculated to a point either ahead of the primary tank or directly ahead of the filter.

Allison (Corpus Christi) authored an interesting article (*Sew. Wks. Jour.* 4, 729-733 (1943)) regarding trickling filter operation as practiced at Corpus Christi. Among other things, he points out that with the original motor-driven distributors the importance of continuous operation to maintain high constant efficiency was proved. By careful adjustment of distribution, and with continuous distributor operation, average B.O.D. reductions exceeded 90 per cent. When the load increased some plant additions were made, among them a change in rotary distributors to the two-compartment arm reaction type. The average B.O.D. reduction then dropped to about 80 per cent due to interruption of operation of the reaction-type distributors during the low night flows. By recirculating 1,000 gpm. of underflow from the final settling tanks, the reaction distributors are kept in constant motion, and the average B.O.D. reduction increased to 90 per cent and above. A major advantage of recirculation at Corpus Christi, in conjunction with the chlorination of the filter effluent, is in controlling odors and *Psychoda* flies, as described elsewhere in this summary.

A classic example of the effect of recirculation in increasing filter efficiency is the experience of Downes at Plainfield. The average sewage flow is 4.25 mgd., and filter effluent is recirculated to maintain a constant rate of 7 mgd. to the filters, which is the maximum capacity of the fixed-nozzle distribution system at mean head in the dosing tank. Motor-operated butterfly valves on the dosing tank outlets have a 35-second cycle from zero to full head, which constantly changes the conformation of the spray, thus covering all parts of the filter area. Reference to Tables I and II indicates that with an average B.O.D. load to the filters of 1,080 lbs. per acre-foot per day an average B.O.D. reduction of 92 per cent was obtained by the filters, and an over-all reduction of 97.8 per cent. As previously discussed in this summary, recirculation at the Plainfield plant also effectively controls *Psychoda* flies, and results in continuous filter unloading.

Hager (San Bernardino, Calif.) recirculates 20 per cent of the plant effluent back to the dosing tanks in order to reduce the dosing cycle and increase plant efficiency. He reports this practice also assists in odor control. Spiess (Litchfield, Ill.) recirculates continuously from the final tank to the raw sewage wet well, and he reports that this practice improves the effluent, aids in filter fly control, and helps keep down ice at the filter during winter operation.

Table VI

EXPERIMENTAL TREATMENT OF HUMUS SLUDGE AT DAYTON, OHIO

Jar Number	Treatment	Final pH	Settling and Compaction	Supernatant Quality	Rising Time (hr.)
1 and 2	None	7.0	Poor	—	2*
3	5 min. mech. agitation	7.2	Good	Turbid	5+
4	10 min. mech. agitation 85 ppm. lime	8.4	Better than No. 3	Turbid	5+
5	10 min. mech. agitation 171 ppm. $FeCl_2$	6.8	Slower compaction	Clear	5+
6	10 min. mech. agitation 256 ppm. $FeCl_3$	6.4	Same as No. 5	Very clear	5+
7	10 min. mech. agitation 85 ppm. lime 171 ppm. $FeCl_3$	7.0	Same as Nos. 5 and 6	Very clear	5+

*Rising of sludge began in 15 min.

Humus Sludge

Most of the smaller plants reported that humus sludge accumulations are removed from the final settling tanks, by pumping or gravity flow, from once to six times daily depending upon local factors. The larger plants in general reported longer or more frequent periods of humus pumping. Humus sludge is pumped eight hours daily at Akron, and continuously at Dayton and Fort Dodge. Humus sludge is either pumped back to the raw sewage and the combined sludge from the primary tank pumped to the digester, or the humus sludge is pumped directly to the digester. The former practice is by far the more common.

Two of the contributing plants reported unusual practices in the handling of humus sludge, those plants being Albemarle, N.C., and Dayton, Ohio.

Moore (Albemarle) reports the interesting use of chemical precipitation of the filter effluent. Sufficient head is available so that the dosing siphon air piping is blocked and the flow is allowed to fill the dosing tanks and pass through the overflow to the distributors. The sewage flow to the distributors is thus reasonably uniform, making chemical dosage of the filter effluent much easier to control. Moore states:

"The need of chemical precipitation was not dictated by the continuous unloading of the filters nor the need for concentrating the final tank sludge. It is true that it helped both of these in our plant, but the main reason was to lower the suspended solids and B.O.D. so that the effluent could be passed into a small creek which dries up at times in the summer months. A considerably lower dosage of chlorine is needed to kill the bacteria in this chemical precipitation plant effluent and quite a saving is accomplished while having a purer effluent.

"We have tried ferric chloride, 'Ferrisul,' ferric sulfate, 'Ferri-floc,' 'Ferrichlor,' copperas, activated alum, and for the past several years we have been using alum only, without lime, as we have plenty of alkalinity added in our industrial dye wastes, along with plenty of sodium chloride.

"We are at present using an average dosage of 60 ppm.—our minimum dosage for domestic sewage runs around 30 ppm. Some of our dye waste will take dosages up to 150 ppm. to produce a suitable floc and then the color will remain at times. Considerable experimentation has been carried out with various dye wastes as to chemical dosages required. The flocculation period is 36 minutes per million gallons per 24 hours. (The average final settling period is 2.07 hrs.)

"In answer for data on the per cent solids of the final tank sludge after chemical precipitation, we are submitting the following averages: per cent moisture, 96.2; per cent dry solids, 3.8; per cent volatile matter, 51.7. Considerable trouble was experienced when pumping this chlorinated sludge directly to the digesters. By keeping a graphic record of the per cent moisture at different elevations in the sludge tanks, we could see the effects the secondary sludge had on settling and digestion. Curves on per cent digested at these various elevations within the sludge tanks were not satisfactory, and therefore this secondard sludge is drawn directly to the head of the plant and mixed with the incoming sewage. Our digesters are kept at a temperature of 100° F. for faster digestion—15 days—with a quicker settling period."

Moore also reports that the chemical dosage is based on the alkalinity rather than on the variable pH. Digester supernatant is also discharged to the flocculation tank and treated chemically.

Huffman (Dayton) reports that the return of humus sludge has resulted in a heavy load to the Imhoff tanks. A year's experimentation was undertaken in the laboratory to devise effective methods of sludge thickening so that the humus sludge could be pumped directly to the digesters, relieving the Imhoff tanks of this extra load. The results of this experimental work as performed by R. Calihan, Plant Chemist, follow:

"The solids concentration of the humus sludge from the secondary clarifiers varies from 0.1 to 5 per cent according to the time of the year (sloughing) and the technique of operation. This variation may occur even within a few hours operation, and so introduces a delicate problem for chemical treatment.

"It was found by jar tests (Table VI) that mechanical agitation alone produces a good floc with subsequent rapid settling, leaving a supernatant having little or no sludge particles. This reaction could be accomplished by agitating the raw sludge as little as five minutes. Settling required another 10 to 30 minutes, depending upon the solids content of the sample. The sludge having received this treatment remained on the bottom of the jar approximately five hours. Room temperature for the tests was between 85 to 95 degrees F. Longer periods of setting may be expected at lower temperatures due to less active bacterial decomposition of the sludge.

"The supernatant of the mechanically agitated sludge always increases in turbidity due to the elutriation phenomenon which occurs. This would indicate a higher B.O.D. for the supernatant and would probably be dependent upon the length of time the sludge was agitated. Tests were run for B.O.D. of supernatant after the sludge was agitated for different lengths of

time, and the following results were obtained:

	5-Day B.O.D. (ppm.)
Untreated sludge	321
Sludge agitated 10 min.	423
Sludge agitated 30 min.	603
Sludge agitated 45 min.	700

"These figures support the contention that longer agitation increases B.O.D., and therefore introduces another operation problem, that is, where should this supernatant liquor be placed in order to eliminate the high oxygen demand it has required from the sludge it washed?

"The alternative to the production of increased B.O.D. (of supernatant) by continued agitation is undoubtedly proper timing of the flocculation to produce compact settling without causing a transition of the soluble material in the sludge itself to the water in which it is immersed.

"Another method of clarifying the supernatant of solids and high oxygen requirement is mechanical agitation with addition of chemicals. This, too, requires rather careful control in that the chemicals necessary for proper precipitation of the dissolved and suspended solids are dependent upon the solids content of the incoming sludge, which, as previously stated, is quite variable. From tests already conducted, it was found that rather high dosages of chemicals were necessary to produce a clear supernatant with a pH of 7.0. For instance, 10 grains per gallon ferric chloride and 5 grains per gallon lime were required to get a clear supernatant and even higher dosages of alum were added for the same results. At present, tests remain to be made to determine the B.O.D. of supernatant from the chemically clarified sludge."

Based upon these results, a humus thickening tank 78 ft. x 10 ft. x 10 ft. water depth has been constructed at Dayton. Mechanical flocculation is provided, and the sedimentation period is 3.83 hr. The tank will operate continuously and is equipped with a sludge collector. The supernatant from this tank can be discharged to the plant effluent, back to the filters, or pumped to the garbage grinder to supply the water needed there. Huffman states it was hoped to obtain 5 per cent sludge from this installation and pump it directly to the digesters. Operation results are not yet available.

Industrial Wastes

No summary of trickling filter operation experiences would be complete without some reference to industrial wastes. Trickling filters are extremely versatile and are capable of providing treatment for a wide variety of industrial wastes provided loading limitations are respected, and provided the waste in question is not in too great concentration, is not in toxic concentration, and that it contains the necessary nutrient material to sustain the biological life on the filter media. Many industrial wastes for which separate treatment is expensive and often impractical are treatable in combination with domestic sewage, provided that precautions are taken against shock loads and provided the industrial wastes are not too great a percentage of the combined flow. Many difficult industrial waste problems have bowed to trickling filters, properly applied.

Eighteen of the plants contributing to this summary receive industrial wastes of consequence. Barnes (Bowling Green, Ohio) reports that the population equivalent from tomato cannery wastes often triples the domestic load. The tomato wastes are received as shock loads after pretreatment to the extent of a fine screen and grit chamber. The plant was designed for a high population equivalent and effective treatment is provided. Schaetzle (Akron) has rubber wastes to contend with, and his interesting report on this problem is contained in *Sew. Wks. Jour.* 17, 497-501 (1945). Hatfield (Decatur) reports an industrial wastes loading from a large corn products plant of 60,000 to 100,000 population equivalent, with peak loads of 160,000 on some days. Through considerable work with the industry, Hatfield succeeded in having recovery procedures installed by the industry. With careful operation by the industry the industrial wastes population equivalent at Decatur can be kept to less than 100,000. The Decatur plant contains activated sludge units in addition to the trickling filters.

Winfrey (Des Moines) reports that 1 mgd. of packinghouse wastes are received at the plant, resulting in a large quantity of screenings to grind, much grease to skim and barrel, and heavy production of digester gas (over 2 cu. ft. per capita daily). He reports that a revenue of $16,346 from the sale of excess gas and $1,439 from the sale of grease was derived during the 1944 fiscal year. Mackin (Madison) reports that 2 to 3 mgd. of packinghouse wastes are included in the total daily flow of 12 to 14 mil. gal. The packinghouse wastes are pretreated. The trickling filters at Madison are used to treat the excess load above the capacity of the activated sludge process.

Magennis summarizes the industrial waste problem at Fort Dodge as follows:

"Contributors of industrial wastes include creameries, poultry houses, a serum manufacturing plant, a rendering company, and a meat packing plant which we usually consider as our sole contributor of industrial wastes because the others are of no particular magnitude. The packing plant contributes about 0.60 to 0.80 mgd. This is about 21 per cent of the total sewage flow. This waste contains about 68 per cent of the suspended solids loading on the plant and about 74 per cent of the B.O.D. load. The plant was designed for 7,700 lb. of B.O.D. per day and a population equivalent of 36,000. Last year the average daily load was 15,140 lb. of B.O.D., 12,350 lb. of suspended solids and a population equivalent of 89,060. The packing plant waste undergoes no pretreatment other than a final grease skimming process at the packing plant. Other than the terrific overload, the chief effect on treatment seems to be caused from large quantities of grease lost by the packing company. We have reclaimed and sold an average of 338 lb. of grease per day last year. (Total revenue from grease sales in the 1943-44 fiscal year was $2,697.) This grease tends to cling to the pipes, decreasing their capacities to the extent of nearly complete stoppage at times, especially in the suction pipe of the grease pit. The walls of the wet wells have to be scraped free of grease quite often. The walls of the control pit, which is ahead of the main lift station, are scraped at least once every two weeks. The grease accumulates here in such large chunks at times that they restrict the flow to the plant and by-pass it to the river. These large chunks are accumulations that have been freed from the inside of the sewer line between the control pit and the packing plant."

Magennis reports a population equivalent for the packinghouse wastes of 42 per hog killed, with a range by monthly averages from 25 to 64.

Simonton (Griffin, Ga.) reports cotton mill wastes are received with no pretreatment or control of the discharge rate. He also advises that oil and grease cause some trouble by forming a film on the filter media. Williams and Malone (Durham, N.C.) report dyes from hosiery mills are received after pretreatment with lime. They report no difficulty if the wastes are not discharged as shock loads.

Mattson (Oconomowoc, Wis.) notes that 40 per cent of the total flow is due to wastes from a condensery and malted milk plant. Pea cannery wastes of 60,000 to 240,000 gpd. are received seasonally without pretreatment. He states that the pea cannery wastes result in a heavy growth on the filter media.

Hager (San Bernardino) reports 1,000 gal. of gunk is discharged to the sewers periodically, leaving a distinctive odor throughout the plant which persists at the filters for many hours. Hager observes that the gunk probably affects the digesters, as does 1,000 gallons of cromic acid discharged periodically to the sewers.

Shick (Van Wert, Ohio) reports that installation of a rotary screen by a canning company has permitted his plant to handle this load without difficulty, together with a heavy milk wastes load. He also commented that tar and oil discharged from an artificial gas plant became so bad that the wastes had to be directed to the stream. The tar and oil filled the digester and almost completely destroyed the effectiveness of the filters. The latter units required six months to recover.

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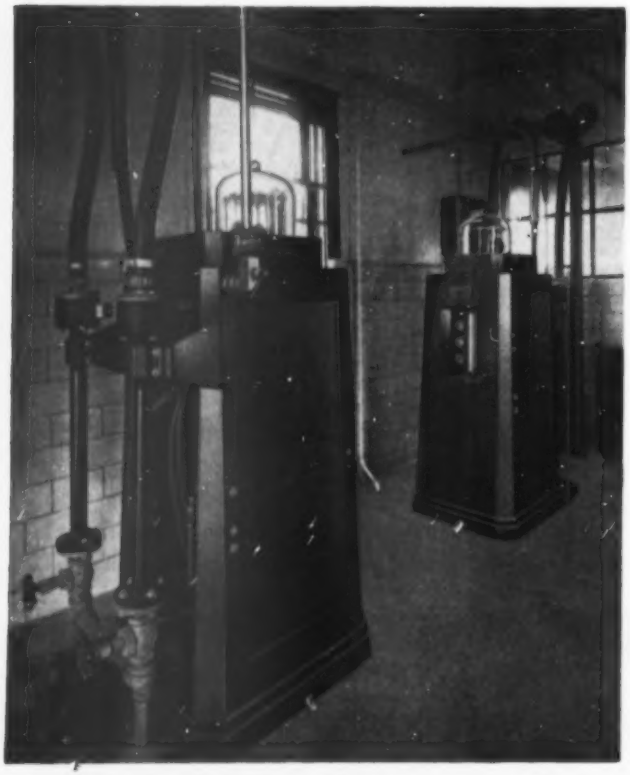
The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



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ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

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FUNDAMENTALS OF CHLORINATION OF SEWAGE AND INDUSTRIAL WASTES*

By EDWARD W. MOORE

Assoc. Prof. of San. Chem.,
Harvard University,
Cambridge, Mass.

CHLORINE is probably the most powerful and flexible tool that chemical science has provided for the sanitary engineer. As an illustration of its versatility, we may examine its application to the wastes which we discharge into our streams. Here we demand that it do three major jobs: first, the elimination of pathogens from the wastes, so that the stream may be safely used as a source of water supply or as a place for bathing; second, the destruction or modification of decomposable organic substances contained in the wastes, so that their biochemical oxygen demand may be reduced, or at least delayed in its exertion; and third, the destruction of chemicals present in the waste which would react directly with oxygen, such as sulfides, sulfites, and ferrous iron.

On all of these jobs, chlorine is capable of turning in a creditable performance, provided that we take account of the limitations inherent in its chemical behavior. It is this behavior, and the concurrent limitations on the powers of chlorine, that are to be discussed in this article.

Chemistry of Chlorine And Chlorine Compounds

Liquid Chlorine. The element itself has the formula Cl_2. It is a greenish gas at ordinary temperatures and pressures, can readily be liquefied at pressures of the order of 50-150 psi., and can thus be contained in pressure vessels and tanks. The commercial product is 99.99% pure, and is the cheapest form of chlorine where the consumption is large. The gas is quite soluble in water, forming a solution containing 0.7 per cent by weight at 68°F. and 0.5 per cent at 92°F. It therefore lends itself readily to solution-feed, but requires special regulating devices to control the flow of the gas by regulation of pressure or vacuum in a chamber.

Certain precautions need to be observed in its application. It is a highly toxic substance even in small concentrations, as shown by Table I, taken from a publication of the Wallace and Tiernan Co.

Table I
PHYSIOLOGICAL EFFECTS OF CHLORINE

	ppm. by volume, in air
Least detectable by odor	about 3.5
Produces throat irritation	15
Produces coughing	30
Dangerous for 30-minute exposure	40-60
Rapidly fatal	1000

Other forms of chlorine or chlorine compounds, include the hypochlorites of calcium and sodium; the ammonia-chloramine compounds formed between chlorine and ammonia; chlorine dioxide; and such special complex chlorine compounds as succinchlorimide, $(CH_2\,CO)_2\,NCl$, Halazone, $HOOC\text{-}C_6H_4\text{-}SO_2\,NCl_2$ and chloramine-T, $CH_3\,C_6\,H_4\,SO_2\,Na\,NCl$.

"Available" Chlorine

The active portion of all of these chlorine compounds is that part of the chlorine content of the compound which possesses a valence number higher than—1. Since the amount and kind of active chlorine vary widely in the compounds, it has become the practice to measure the activity in terms of the oxidizing power of the compound, and express this in terms of equivalent chlorine. This measure is called the percentage of available chlorine.

To the eternal mystification of students, the available chlorine of a compound may amount to more than the total chlorine content of the compound, especially in the case of the hypochlorites. If the quantity had been called "chlorine equivalent" or some other more accurate name, the difficulty would probably not arise. It may help to remember that "per cent available chlorine" is really analogous to "alkalinity as calcium carbonate," and that there might even be no chlorine at all in the compound, or, in other words, that it is equally legitimate to speak of the "available chlorine" of ozone, hydrogen peroxide, or any other oxidizing agent in view of the way in which "available chlorine" is defined and determined.

For purposes of illustration, the percentage of "available chlorine" by weight that would be found for various pure compounds is computed and compared with the percentage of chlorine by weight actually present in the compound. (See Table II.)

Table II
ACTUAL AND "AVAILABLE" CHLORINE IN PURE COMPOUNDS

Compound	Mol Wgt.	Mols* of Equivalent Cl	Per cent of Chlorine, by weight	
			Actually Present	"Available"
Cl_2	71	Cl_2	100.0	100.0
$CaClOCl$	127	Cl_2	56.0	56.0
$NaOCl$	74.5	Cl_2	47.7	95.4
$Ca(OCl)_2$	143	$2Cl_2$	49.6	99.2
NH_2Cl	51.5	Cl_2	69.0	138.0
$NHCl_2$	86	$2Cl_2$	82.5	165.0
Cl_2O	87	$2Cl_2$	81.7	163.4
$HOCl$	52.5	Cl_2	67.7	135.4

* Number of mols of chlorine that would have an oxidizing capacity equivalent to one mol of the compound.

Behavior of Chlorine Compounds In Water

When chlorine, Cl_2, dissolves in water, it hydrolyzes immediately according to the reaction

$$Cl_2 + H_2O \rightleftarrows HOCl + H^+ + Cl^-$$

The equilibrium condition is given by the expression which follows:

$$\frac{[HOCl]\,[H^+]\,[Cl^-]}{[Cl_2]} = K_h$$

The value of K_h is such that in waters of pH value above 3.0 and for concentrations of total chlorine below 1000 ppm., no measurable quantity of Cl_2 exists in the solution, all chlorine being present as HOCl.

For example, Jakowkin's[1] value for K_h at 15°C. is 3.16×10^4, and if we assume a solution receiving a dose of 7.1 ppm. total chlorine (10^{-4} molar) at a pH value of 7.0, the ratio of HOCl to Cl_2 present after reaction will be

$$\frac{(HOCl)}{(Cl_2)} = K_h \times \frac{1}{(H^+)\,(Cl^-)} = \frac{3.16 \times 10^4}{10^{-7} \times 10^{-4}} = 3 \times 10^{15}$$

Furthermore, it has been shown that the rate of the reaction is such that equilibrium is reached within a few seconds at ordinary temperatures. Hence the conclusion is inescapable that when water or sewage is treated with gaseous chlorine under any condition likely to be encountered in practice, all the chlorine is at once converted to HOCl.

Hypochlorous Acid in Water

Hypochlorous acid is a weak acid and consequently ionizes in water according to the equation

$$HOCl \rightleftarrows H^+ + OCl^-$$

This equilibrium is instantaneous and reversible, and is governed by the equation

$$\frac{[H^+]\,[OCl^-]}{[HOCl]} = K_i$$

or, by rearrangement,

$$\frac{[OCl^-]}{[HOCl]} = \frac{K_i}{[H^+]}$$

Thus any free chlorine or hypochlorite added to water will immediately distribute itself into the species HOCl and OCl^-, and the ratio of the two will be controlled entirely by the pH value of the water. This fact is of the greatest importance with respect to disinfection, since HOCl and OCl^- differ greatly in killing power.

Substitution of the proper values of K_i (estimated from the results of a number of workers as 3.3×10^{-8} for 20°C. and 2.1×10^{-8} for 0°C.) will reveal that at pH 5.0 or below almost all of the chlorine is present as HOCl, whereas above pH 10.0 nearly all of it exists as OCl^-.

* Presented before the Univ. of Mich. School of Public Health Inservice Training Course in Technical Problems in Sewage and Industrial Waste Disposal, and here published by permission.

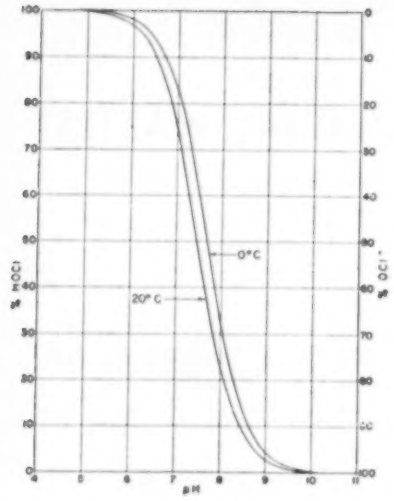


Fig. 1—Relative amounts of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) present at various pH values

Table III and Fig. 1 show the approximate percentages of total chlorine present at HOCl and OCl^- at various pH values for temperatures of 0° and 20°C.

All of the hypochlorites, when placed in water, will immediately ionize to give OCl^- ion:

$$Ca(OCl)_2 \longrightarrow Ca^{++} + 2OCl^-$$

The hypochlorite ion will then reach precisely the same equilibrium as given above by combination with the hydrogen ions of the water:

$$H^+ + OCl^- \leftrightarrows HOCl$$

It must be pointed out that the pH value that will control is the pH value reached after the addition of the chlorine compound, not the original pH value of the water. Since the addition of chlorine tends to lower the initial pH and the addition of hypochlorites tends to raise it, the addition of equivalent amounts of chlorine in the form of chlorine or hypochlorites will not be expected to yield the same results unless the amounts added are so small that the pH value of the water remains unaffected.

Chloramines

Hypochlorous acid reacts with ammonia and with many of the more complex derivatives of ammonia to produce compounds known as chloramines. These retain some of the oxidizing properties of the hypochlorous acid, so that they respond to the ortho-tolidine and starch-iodide tests in varying degrees. They also retain the disinfecting properties of hypochlorous acid in some degree. We cannot be sure that the responses of these compounds to the usual tests for chlorine are correlated with their efficiencies as disinfecting agents until all possible forms of chloramines have been investigated. There is some indication that some of the chloramine compounds formed when sewage is chlorinated respond to the usual tests for chlorine without having any appreciable disinfecting action. Others do not respond appreciably to chlorine tests, but seem to possess material disinfecting powers.

Table III
PERCENTAGES OF CHLORINE AS HOCl AND OCl^- AT DIFFERENT pH VALUES

	Percentages of Total Chlorine as			
	HOCl		OCl^-	
pH	0°C	20°C	0°C	20°C
4.0	100.0	100.0	0.00	0.00
5.0	100.0	99.7	0.00	0.3
6.0	98.2	96.8	0.8	3.2
7.0	83.3	75.2	16.7	24.8
8.0	32.2	23.2	67.8	76.8
9.0	4.5	2.9	95.5	97.1
10.0	0.5	0.3	99.5	99.7
11.0	0.05	0.03	99.95	99.97

The simple ammonia chloramines have been studied by a considerable number of workers, and a detailed investigation into equilibria and rates of formation of these compounds is being carried on at the Laboratories of Sanitary Engineering of the Harvard Graduate School of Engineering. It is known that three chloramines are formed, in accordance with the following reactions:

$$NH_3 + HOCl \longrightarrow \underset{\text{monochloramine}}{NH_2Cl} + H_2O$$

$$NH_2Cl + HOCl \longrightarrow \underset{\text{dichloramine}}{NHCl_2} + H_2O$$

$$NHCl_2 + HOCl \longrightarrow \underset{\text{nitrogen trichloride}}{NCl_3} + H_2O$$

The early work of Chapin, done at concentrations much higher than those employed in chlorination, indicated that above pH 8.5 only monochloramine is formed, that varying mixtures of mono- and dichloramine appear between pH 8.5 and 5.0, and that dichloramine is the sole form existing at pH 5.0 to 4.4, below which nitrogen trichloride begins to appear. It is not assured that these relationships will hold for the concentrations of chlorine used in practice. However, the Harvard Research previously mentioned, which has employed ultra-violet spectroscopy to differentiate between chloramines in solution, has shown that the ratio of mono- to dichloramine is controlled by the equilibrium

$$2\ NH_2Cl + H^+ \leftrightarrows NH_4^+ + NHCl_2$$

The mathematical expression controlling this equilibrium is

$$\frac{(NH_4^+)\ (NHCl_2)}{(H^+)\ (NH_2Cl)^2} = K_{eq}$$

and the value of the constant has been determined as 6.7×10^8 at about 25°C. For the concentrations of total chloramine used in practice, and for a weight ratio of total chlorine to ammonia nitrogen of 5 to 1, Table IV gives the relative percentages of monochloramine and dichloramine present at various pH values. These values agree approximately with those of Chapin, and indicate that the differences in distribution are not too great between concentrated and dilute chloramine solutions. However, Chapin's statements as to the formation of nitrogen trichloride may be inaccurate, and it may exist at much higher pH values. The disinfecting efficiency of chloramine solutions will be dependent on the ratio of the different chloramines present and therefore on the pH value.

Table IV
CHLORAMINE DISTRIBUTION AT VARIOUS pH VALUES

	Percentage of Chlorine Present as	
pH	Monochloramine	Dichloramine
5	16	84
6	38	62
7	65	35
8	85	15
9	94	6

Rate of Formation of Ammonia Chloramines

The rate at which chlorine reacts with ammonia to form the chloramines is also under study at Harvard. So far, the rate of the first step, which results in monochloramine,

$$NH_3 + HOCl \longrightarrow NH_2Cl + H_2O$$

has been investigated. The reaction is proved to be in accordance with the equation as written. This reaction is very much influenced by the pH value of the solution. The kinetic expression for the rate of a reaction of this type is

$$-\frac{dc}{dt} = k_r \cdot C \cdot N$$

where

$-\frac{dc}{dt}$ = instantaneous rate of reaction, mols of HOCl or NH_3 per minute

C = concentration of chlorine, mols per liter

N = concentration of ammonia N, mols per liter

The effect of pH value on the rate of reaction at 25°C. is shown in Table V.

Between pH 6.5 and 11.0 the rates are too fast to be measured accurately by experimental methods, but can be calculated from the experimental values available by means of theoretical considerations. These calculations show that the maximum rate of formation of monochloramine appears at pH 8.3; at this point k_r is about 5×10^6. From these values the rate of formation of monochloramine can be calculated for any given set of conditions.

For example, a water at 25°C. receiving 0.8 ppm. of chlorine and 0.32 ppm. of ammonia nitrogen will convert 99 per cent of the chlorine to monochloramine in 1 minute at pH 8.3, but at pH 5 the required time will be 210 minutes, and at pH 11.0 it will be 90 minutes. The reaction rates also vary greatly with temperature, increasing by a factor of 2.0 to 2.5 for every 10°C. increase in temperature.

The rates of formation of dichloramine are being similarly studied, but the work is not yet complete. The optimum pH value is lower, as would be expected, but the variation in rate with pH forms a very similar pattern. Some work has also been

Table V
MEASURED RATES OF FORMATION OF MONOCHLORAMINE AT VARIOUS pH VALUES

pH	$K_r \times 10^{-3}$
4.6	8.9
4.71	13.0
6.11	220.0
6.49	580.0
10.95	92.0
12.05	7.4

done on the rate of the breakpoint reaction; this reaction evidently starts with dichloramine, which decomposes into unknown end-products. The observed rates are dependent on the pH value and chlorine-ammonia ratio; a maximum in the rate occurs at a pH of about 7.3.

Determination of Chlorine

Since the different species of chlorine compounds outlined above have disinfecting efficiencies differing greatly from each other, a rational study of disinfection by chlorine compounds demands accurate methods for determining the amounts of the various species present. Assuming that the equilibrium relationships between HOCl and OCl^- and between ammonia and the various chloramines are, or can be, worked out, it will be sufficient to differentiate between chlorine present as "free residual chlorine" (HOCl and OCl^-) and that present as "combined" residual chlorine (chloramine). It will eventually be necessary to have means for differentiating between the ammonia chloramines and the complex, less active chloramines that may be formed when chlorine is added to sewage.

The starch-iodide test and the standard orthotolidine test are of no value for this purpose, since they respond to all of the chlorine compounds discussed, and probably to many of the complex chloramines. The ortho-tolidine-arsenite test differentiates between hypochlorite chlorine and the ammonia chloramines, by virtue of the fact that the reaction with ortho-tolidine is much more rapid for the former than for the latter. The addition of sodium arsenite stops the reaction after all the hypochlorite has reacted and, at least approximately, before the ammonia chloramines have reacted.

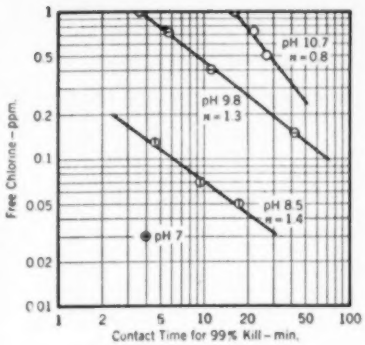
The O.T.A. test is being investigated in our laboratory, and the results show that a correction must be applied to the readings obtained in order to compensate for the amount of ammonia chloramine that reacts with ortho-tolidine before the arsenite is added.

$$\text{Hypochlorite Cl} = \frac{(\text{O.T.A.}) - F_t(\text{O.T.})}{1 - F_t}$$

This equation (O.T.A.) represents the reading obtained with ortho-tolidine followed by arsenite, and (O.T.) represents the reading obtained with ortho-tolidine alone. F_t is really the fraction of chloramine which reacts in the time between the addition of the ortho-tolidine and the arsenite, and depends on three factors: the amount of ortho-tolidine solution used, the time elapsing between the two additions, and the temperature, as shown in Table VI. The accuracy of the test may thus be improved by lowering the temperature or by cutting down the time elapsing between the additions of ortho-tolidine and arsenite. Since the reaction between ortho-tolidine and the chloramines appears to be catalyzed by chloride ion, it may be possible to improve the differentiation by using some acid other than HCl. This factor is now under investigation.

Chlorine in Sewage

In sewage, the presence of large amounts of substances that react with chlorine must be considered. It is rare that sufficient chlorine is added to produce a permanent appreciable content of HOCl and OCl^-. The active chlorine remaining in sewage after ordinary chlorination will be present largely in the form of ammonia chloramines and the more complex chloramines



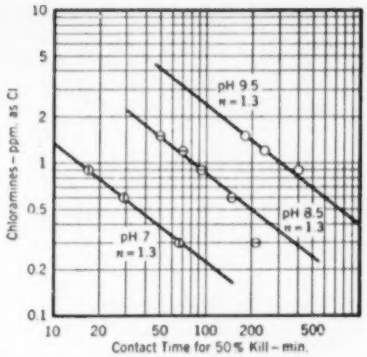


Fig. 2—Disinfectant Concentration vs. Contact Time Requirements for free chlorine on left—for chloramine chlorine on right

Table VI
CORRECTION FACTORS FOR THE O.T.A TEST

Temp. °C.	Temp. °F.	Value of F, for 5 — ml O. T. 20 sec.	5 — ml O. T. 3 sec.	1 — ml O.T. 20 sec.	1 — ml O.T. 3 sec.
0	32	0.077	0.012	0.034	0.005
5	41	0.12	0.019	0.054	0.008
10	50	0.18	0.029	0.082	0.013
15	59	0.26	0.044	0.12	0.019
20	68	0.34	0.061	0.16	0.026
25	77	0.50	0.100	0.26	0.044

formed by reaction of the chloramine with nitrogenous organic compounds. The bulk of the chlorine added will of course have been converted to inactive chlorine. At normal sewage pH values, the formation of ammonia chloramines takes place in a few minutes; however, as previously shown, if the pH value is high or low, the slow rate of ammonia-chloramine formation may permit the persistence of HOCl or OCl^- residuals for some time.

Our present methods of determining chlorine residuals in sewage, the orthotolidine and starch-iodide methods, are thus of dubious significance with respect to disinfection, since they represent a complex of chloramino-compounds of highly variable disinfecting powers. This complex must be untangled before we can proceed with fundamental studies of sewage disinfection; so long as this is not done, empirical studies are bound, as they do, to present confusing and conflicting results. A chlorine residual of, say, 0.5 ppm. in one sewage does not necessarily have the same killing power as an equal residual in another sewage, because the chlorine compounds present may be, and probably are, of different composition. Moreover, the killing power of the chlorine compounds present while the chlorine demand was being exerted may have been entirely different, and killing goes on side by side with the exertion of demand. Within reasonably narrow limits of sewage composition, the differences may be small. In the following sections lies what little information can be gleaned from empirical studies.

Disinfection by Chlorine Compounds

It is now pretty well established that oxidation of the living cell is not involved in disinfection by chlorine compounds, but that these compounds enter into reactions with certain of the essential enzymes of the cell, and thus kill by stopping the metabolic processes of the cell. Green and co-workers[4] have studied a number of these enzyme-chlorine reactions. Two factors are thus involved in the ability of a compound to disinfect: its ability to penetrate the cell, and its reactivity toward the cell enzymes. On a more practical plane, the factors that determine the efficiency of disinfection are the nature of the disinfecting agent, the concentration of this agent and the time allowed for its action, the number of organisms present, and the temperature.

Rate of Disinfection

The rate at which disinfection proceeds with time under ideal conditions, namely, constant concentration of disinfecting agent, constant temperature, and the presence of a single species of bacterium of which all individuals are equally susceptible to the agent, is given by Chick's law, where

$$\log \frac{N_o}{N} = rt$$

N_o and N represent the numbers of organisms present at the beginning and after t minutes, respectively, and r is a constant which measures the rapidity of the kill. It is not surprising to find that few experimental studies conform exactly to Chick's law. Generally the rate of kill decreases as time goes on—this reflects the survival of the more resistant individuals, the decline in concentration of the active agent, and a number of other interfering factors. More complicated formulae have been devised to express results of individual studies, but their applicability is limited.

The important thing is that the killing of organisms by disinfecting agents follows a logarithmic law:—that it is the ratio of the numbers of bacteria present before and after disinfection that is significant, not the numbers themselves. This gives theoretical aid and comfort to the engineer's natural tendency to use a percentage:—th terminology "time required to kill 50 per cent, or 90 per cent of the bacteria present" has a real significance, and the total number of bacteria is of less importance. The engineer's tendency to use logarithmic scales and plots is also in line with reality.

Concentration of Organisms

Far too little is known about the effect of total numbers of organisms on the rate of disinfection. Such results as do exist indicate that the effects are slight with changes in the total number as great as tenfold. This is a field of research that would have considerable significance for the disinfection of sewage, where the numbers of organisms are high and widely variable.

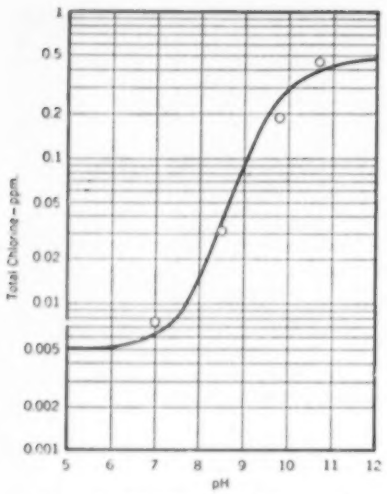


Fig. 3—Relative disinfecting efficiency of HOCl and OCl⁻

Concentration of Disinfectant

An examination of data from many sources shows that the time required to effect a constant percentage of kill of bacteria or other organisms by means of any disinfectant is dependent on the concentration of the disinfectant in the following manner:

$$C^n t = \text{Const.}$$

where C represents the concentration of disinfectant, t represents the time required to kill a selected percentage of the organisms, and n is a numerical value which depends on the disinfectant, the organism, and the temperature. (A series of such plots is shown in Fig. 2, with the left hand diagram representing free chlorine requirements for a 99 per cent kill of bacteria and the right hand diagram representing chloramine requirements for a 50 per cent kill.) This equation is purely empirical and has as yet no theoretical justification. The constant n is a positive number, and its numerical value, in the studies so far made, ranges from 0.75 to 2.00, with 1.00 as the most common value. It is a measure of the change of killing efficiency of the disinfectant with change of concentration. Table VII, from the work of Fair, Morris, and Chang[10], shows some of the values obtained for various disinfectants and organisms.

Table VII
VALUES OF n FOR CHLORINE COMPOUNDS

Substance	Value of n for Cysts of E. histolytica	Enteric Bacteria	B. Anthracis Spores	B. Metiens Spores
HOCl	1.0	1.6	0.67	0.9 1.0 0.95
OCl^-	2.0	0.75		
$NHCl_2$	1.0	0.75	0.8	0.8
NH_2Cl	1.0			

Temperature

The effect of increased temperature on disinfection is to increase the kill; the rate of increase follows the law which governs the rate of increase of all chemical reactions with temperature, namely

$$\log \frac{t_1}{t_2} = \frac{E(T_1 - T_2)}{4.575(T_1 T_2)}$$

where the t values represent times required for equal percentages of kill at the absolute temperatures T_1 and T_2, and E is a constant characteristic of disinfectant and organism.

This is a cumbersome expression, and can be simplified by taking the temperature interval as 10°C., whereupon the right-hand side of the equation becomes nearly constant and the ratio t_1/t_2, called Q_{10}, represents the relative increase in disinfection rate for a 10° increase in temperature. For example, if $Q_{10} = 2.00$, the rate is doubled for every 10° rise. Some values of Q_{10} for *E. Coli*, computed by Fair et al[9] from the work of Butterfield, are given in Table VIII.

Table VIII
VALUES OF Q_{10} FOR E. COLI

Aqueous Chlorine pH	Q_{10}	Chloramines pH	Q_{10}
7.0	1.65	7.0	2.08
8.5	1.42	8.5	2.28
9.8	2.13	9.5	3.35
10.7	2.50		

Determination of Relative Disinfecting Power

With the foregoing as a basis, it becomes possible to evaluate the efficiency of any disinfecting agent against any organism, subject to the limitations of experimental techniques. The values so obtained can then be applied to practical problems of waste disinfection, with the assurance that the conclusions drawn rest on sound fundamental knowledge. It is necessary only to take sufficient trouble to identify the agents which are involved in our disinfection operation, and to have at hand, or to secure by controlled experiments, data on the efficiences of these agents against the organisms with which we are concerned.

It is unfortunately not true that the effectiveness of chlorine compounds against the various water-borne pathogens is the same for all organisms, nor is the relative efficiency of the different chlorine compounds the same for all organisms. The groups of organisms in which we are most interested are the following:

1. *Esch. coli*, which, although not a pathogen, is the important type of organism of water contamination.
2. The enteric bacteria, Eberthella, Shigella, Salmonella, and Vibrio species.
3. The intestinal protozoa—for example, E. histolytica.

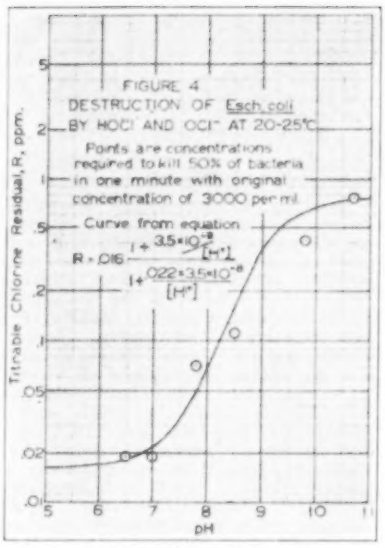


FIGURE 4
DESTRUCTION OF Esch. coli
BY HOCl AND OCl⁻ AT 20-25°C
Points are concentrations
required to kill 50% of bacteria
in one minute with original
concentration of 3000 per ml.
Curve from equation
Trinable Chlorine Residual, R, ppm.
pH

Fig. 4—Destruction of E. coli *by HOCl and OCl⁻ at 20-25° C*

4. Worms, such as the Schistosomes.
5. Viruses, such as that of infectious hepatitis.

In a general way, the results indicate that the enteric bacteria are most easily destroyed by chlorine compounds, and that the cysts of the enteric protozoa are the most resistant. Until further evidence is available, the use of amoebic cysts as indicator organisms for disinfection evaluation is thus suggested.

Efficiencies of HOCl and OCl⁻

It has been apparent for a long time from the decrease in observed disinfection efficiencies with increasing pH values that HOCl is much more effective than OCl^-. Now that values are available for the dissociation constant of HOCl, the proportions of HOCl and OCl^- in any disinfection study involving these compounds alone can be evaluated, and also the relative efficiencies.

If R is the total residual of chlorine as HOCl and OCl^- required to produce a given percentage of kill of a specified organism, A is the concentration of HOCl alone necessary to produce this kill, and B is the ratio of the efficiency of OCl^- to HOCl, the equation is

$$R = A \frac{1 + \frac{K}{(H^+)}}{1 + B\frac{K}{(H^+)}}$$

where K is the previously given ionization constant of HOCl and (H^+) is the hydrogen-ion concentration.

For a kill of 99 per cent of *E. coli* in 30 minutes at 2 to 5°C., the results lead to the equation

$$R = 0.005 \frac{1 + \frac{2.2 \times 10^{-8}}{(H^+)}}{1 + 0.012\frac{2.2 \times 10^{-8}}{(H^+)}}$$

(A plot of this equation is shown in Fig. 3.)

B is 0.012, thus indicating that OCl^- is about 1/80 as effective as HOCl against *E. coli* under the conditions given. In other words, the work done by HOCl alone (at pH 5.0) in a concentration of 0.005 ppm. as chlorine requires, at pH 10.7, where OCl^- is the main constituent, a total chlorine content of about 0.4 ppm.

For a 50 per cent kill of *E. coli* in 1 minute at 20-25°C., calculations from results by Butterfield, Wattie, Megregian, and Chambers [7] give a required dose of 0.016 ppm. of HOCl as chlorine and about 0.75 ppm. of OCl^-, so that under these conditions OCl^- is about 1/45 as effective as HOCl. (See Fig. 4.)

Results are also available for 100 per cent kill of 30 cysts per ml. of *E. histolytica* at 3°C. and 23°C. and contact times of 10 minutes and 30 minutes. Here HOCl is much more effective relative to OCl^- than it is even for *E. coli*, as the following table shows. The required HOCl residuals for 30-min. contact are 1.2 ppm. at 23°C. and 7.5 ppm. at 3°C.

Table IX
Effectiveness of OCl^- Relative to HOCl Against Amoebic Cysts, for 100 Per Cent Kill.

Temperature	Relative Effective Ratio OCl^- to HOCl	
	10-min. Contact	30-min. Contact
3° C.	1/100	1/200
23° C.	1/250	1/400

For other organisms of interest, no results are as yet available. It is reasonable to assume, however, that many of them will require chlorine residuals between the values for *E. coli* and *E. histolytica* cysts. For spores of B. anthracis and B. metiens at 25°C., 30 minutes contact, the HOCl residuals required for 100 per cent kill are 3 pp. and 2 ppm., respectively.

Efficiencies of NH_2Cl and $NHCl_2$

The relative efficiencies of mono- and dichloramine have been investigated in a similar way, although the results are much less complete. (See Fig. 5.) For cysts of *E. histolytica* under the same conditions as previously stated, it is indicated that dichloramine is about 60 per cent as efficient as HOCl, and monochloramine about 22 per cent as efficient, for a contact time of 30 minutes. At pH 4.5, where dichloramine only is present, a residual of 2 ppm. gives 100 per cent kill of cysts, whereas at pH 10.0, with monochloramine only, the required residual is about 5.5 ppm.

Application to Sewage and Waste Chlorination

In the chlorination of sewage and wastes, the economics of the problem usually precludes the addition of sufficient chlorine to satisfy all of the chlorine demand and to convert all ammonia and nitrogen compounds to chloramines. Unless this is done, the existence of HOCl in chlorinated sewage or waste is an ephemeral one, and the chlorine compounds which remain are unfortunately those of relatively low disinfecting efficiency.

If the pH value is sufficiently low, the best of the chloramines, namely dichloramine, will be formed. Some consideration might be given to pH reduction by the addition of acid along with chlorination. This would not only throw the chloramine balance in a direction favorable to dichloramine, but would also reduce the rate of formation of chloramines, as previously shown, thus permitting a longer persistence of HOCl. Studies along this line are recommended to those interested in improving the practice of sewage and waste chlorination.

Real knowledge of the processes by which bacteria are killed in chlorinated sewage and wastes will depend on the development of techniques to identify and determine the species of chlorine compounds present in the chlorinated mixture.

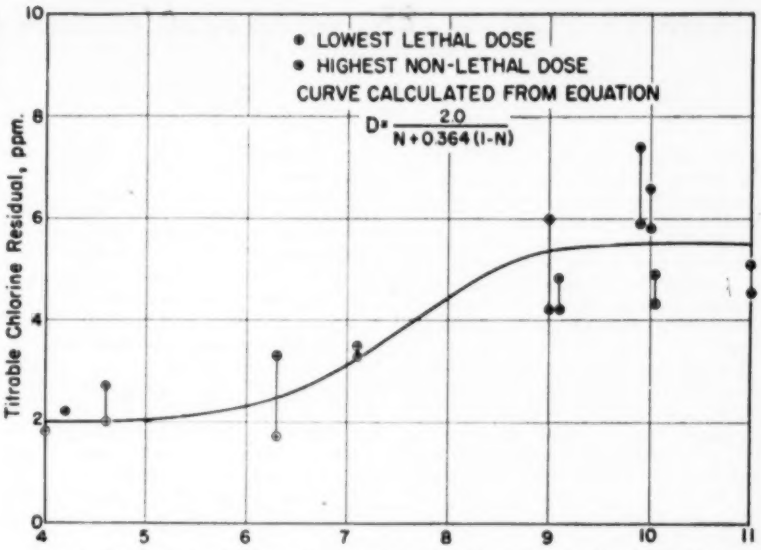


Fig. 5—Destruction of Cysts of E. hystolyica *by chloramines in 30 min. at 23° C*

At present this is a large order, but there are new analytical methods which are promising. One of them, the phenyl-arsene oxide method[8], gives higher readings for residuals in sewage than those obtained by the ortho-tolidine method. This may serve to explain why, in many instances, the killing of coliforms in chlorinated sewage continues when no residual can be determined with ortho-tolidine.

Reduction of B.O.D. by Chlorination

It has been known since the early 1920's that the addition of chlorine to sewage and wastes effects a measurable reduction in the observed B.O.D., and that this reduction is, at least in part, a permanent reduction, involving elimination or alteration of substances capable of exerting B.O.D. A large amount of research has indicated that the application to sewage of enough chlorine to produce a trace of residual after 15 minutes reduces the 5-day B.O.D. by 15 to 35 percent. This reduction amounts to about 2 ppm. of B.O.D. per ppm. of chlorine taken up. Largely on the basis of indirect evidence, it has been concluded that three kinds of reactions are involved:

(1) Direct oxidation, resulting in destruction of B.O.D.-exerting compounds.

(2) Substitution of chlorine for hydrogen. When this substitution takes place on nitrogen atoms, chloro-amine compounds having more or less bactericidal power are formed, as previously noted. When the substitution is on carbon atoms, the compounds are not bactericidal but are no longer available as food.

(3) Addition to unsaturated compounds. This again produces compounds that are not bactericidal but are not available as food.

As to whether the 5-day B.O.D. reduction observed results from a reduction of the total amount of decomposable material or a reduction of the rate at which B.O.D. is exerted, or both, the evidence has not been decisive. Recent studies by Snow[9] have indicated that both the total amounts of B.O.D. and the rates of exertion are reduced. The two factors together account for the observed reduction in 5-day B.O.D. Snow found that chlorination of fresh sewage to a trace of residual at 15 minutes gave reductions of only 10 per cent, as compared to the 15 to 35 per cent usually accepted. Chlorine doses as high as 100 to 300 ppm. were required to secure reductions as high as 35 per cent. Chlorination to the "breakpoint," i.e. to a free HOCl-OCl^- residual, gave reductions as high as 75 per cent, but the amounts of chlorine required would be prohibitive.

Snow accounted for the difference between his 10 per cent reduction and those cited in the literature by showing that the condition and stage of decomposition of the sewage had a great influence on the B.O.D. reduction secured by satisfaction of the 15 minute chlorine demand. For example, if the sewage were held under aerobic conditions for ½ to 2 days before chlorination, then reductions of 25 to 40 per cent of the 5-day B.O.D. could be accomplished by chlorination to a 15 minute residual. One day of anaerobic incubation of the sewage permitted a 23.6 per cent reduction of 5-day B.O.D., as compared with an 11.1 per cent reduction on the same sewage when fresh. Plain aeration of sewage for 30 to 60 minutes, followed by chlorination, also resulted in considerable increases in the 5-day B.O.D. reduction secured. Snow suggested this process as a possibility for sewage treatment to secure results intermediate between those of plain sedimentation and complete treatment.

Conclusion

The chlorination of water, sewage, or waste has been shown to be a complex problem, involving, as it does, not a single disinfecting agent but a number of derivatives of varying effectiveness.

References:

1 Jakowkin, Z., *Physik. Chem.* 29, 654 (1899).
2 Shilov and Solodushenkov, Comptes Rendus Acad. Sci. U.R.S.S. 3:1:17 (1936).
3 Chapin, *Jour. Am. Chem. Soc.* 51, 2112 (1929); 53, 912 (1931).
4 Green, D. E. and Stumpf, P. K., *Jour. Am. Water Works Ass'n* 38, 1301 (1946).
5 Fair, G. M., Morris, J. C., and Chang, S. L., *Jour. New England Water Works Ass'n* 61, 285 (1947).
6 Fair, G. M., et al., *Jour. Am. Water Works Ass'n* 40, 1051 (1948).
7 Butterfield, C. T. and Wattie, E., U.S. Pub. Health Reports 61, 157 (1946).
8 Marks, H. C. and Jower, R. R. *Analytical Chemistry* 20, 1197 (1948).
9 Snow, W. B., Doctoral Thesis, Harvard Graduate School of Engineering (1948).

LIMITS FOR TOXIC WASTES IN SEWAGE TREATMENT*

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AN examination of the recent literature reveals a large number of articles describing the objectionable effects of various industrial wastes on sewage treatment. The factual evidence from these reports shows that these wastes have caused various troubles, from "excessive foaming" or "retarded digestion of sludge" to a complete breakdown of treatment plant facilities.

It is apparent that the deleterious effects of any industrial waste vary inversely with the dilution afforded by the sewage. Thus, the wastes from a certain industry in a small community might disrupt the treatment plant, whereas its effect in the sewage of a large city would be inconsequential.

Effects of Toxic Wastes

The objectionable effects of an industrial waste may be due to one or more of its various constituents. As an illustration, in the manufacture of mouton fur the following substances may cause trouble in treatment:

1. Grease and excess alkali from the scouring of the skins clog the sewers and retard biological treatment.
2. Heavy suspended solids both from the washing and the tanning overload primary treatment.
3. Toxic chromium from the mineral tan prevents digestion of sludge.
4. Large quantities of organic material having an excessively high oxygen demand overload oxidation processes.

Other wastes have their own characteristic effects. Tanneries, breweries, canneries, slaughter houses, textiles, rubber, metallurgical wastes, and numerous others, have different effects on sewage treatment.

Chromium salts, usually reported in the form of metallic chromium, have different effects on different units of a sewage treatment plant. The chromium is in the trivalent form in spent chrome alum in the wastes discharged from a tannery using a mineral tan. Chromium in this form will precipitate almost quantitatively in an alkaline solution such as sewage, and will be removed as sludge to digestion tanks, where digestion will be retarded or practically stopped. If secondary treatment is used there will probably be very little trouble biologically. On the other hand, if the chromium compounds are discharged from a plating establishment or from anodyzing of aluminum, the chromium is chiefly in the hexavalent form. Chromium cannot be precipitated under ordinary conditions in this form. Therefore, the effect on sludge digestion is very much less. However, in the hexavalent form the chromium is much more toxic, and when present in sufficient quantities will kill the organisms in filters or in activated sludge. The tolerance concentration is controversial. It has been reported to the writer that quantities up to 25 p.p.m. can be handled continuously. Edwards found that shock loads of about 40 p.p.m. slowed up nitrification and caused deterioration in the appearance of activated sludge effluent. Information is still lacking as to the quantity of chromium which is permissible in sewage under the following variable conditions:

1. Type of chromium, trivalent or hexavalent.
2. Type of sewage treatment, such as primary and secondary.
3. Continuous flow versus shock loads over a period of a few hours.

Copper is a toxic substance easier to evaluate. As reported by Mohlman an excess of 1 p.p.m. has caused trouble.

Acid-iron wastes have caused trouble at Worcester, Fostoria, and in many other places.

Daily, weekly or monthly analyses have usually been reported. The question arises as to whether or not the trouble was caused by intermittent discharges of pickling liquors high in iron or acid content, or by a continuous discharge of wastes containing much smaller quantities of iron and acid. Zinc has been reported as detrimental to sludge digestion at Fostoria, Ohio.

Cyanides of 5 p.p.m. discharged continuously have an inhibiting effect on activated sludge treatment. Doses of 20 p.p.m. are reported as having an immediate effect on activated sludge, but after removal of the cyanide, the sludge recovers. Siebert reports that as low as 1 p.p.m. is toxic to biological activities. On the other hand, filtration of much higher concentrations of cyanide, through sand or coke breeze, has been suggested as a method of treatment.

From another point of view cyanides should not be permitted in sewage because of the slight possibility of acid wastes being present at the same time and therefore possible liberation of hydrocyanic acid.

Brewery wastes have interfered with sewage treatment at Jeanette, Pennsylvania. It was found during a recent investigation that the B.O.D. population-equivalent of the waste from a single brewery was greater than the population of the entire city.

Rubber wastes at Akron so overloaded the primary treatment units that the sewage plant reached its designed capacity long before the estimated time.

Substances such as acids, alkalies, silt, plastics, and grease, which cause localized troubles in a sewer, may also cause serious results at the sewage treatment plant.

Soluble cutting oils, while affecting treatment to some degree, are objectionable in that they pass through tanks unchanged and cause marked objectionable effect on the appearance of the receiving stream.

Control of Toxic Wastes

The writer takes the view that industrial wastes should be admitted to municipal sewer systems to the extent that they do not cause breakdown of the collection or treatment facilities either physically or biologically, or so overload the various units that the effluent is impaired to an objectionable degree. In other words, the presence of industrial wastes may cause temporary overloading and accompanying operational vexations, but pollution abatement is nearer being solved and the public better served by treatment of all wastes possible with the sewage in one plant, under the supervision of competent operators.

TABLE I

Concentration Limits for Toxic and Deleterious Wastes in Composite Sewage of Treatment Plant Influent*

Names of Items	Primary Treatment		Secondary Treatment
	No Sludge Digestion	Sludge Digestion	
pH index	5.0	6.5	6.5
Total iron (p.p.m.)	5.0	5.0	5.0
Copper (p.p.m.)	3.0	1.0	1.0
Chromium (p.p.m.)	5.0	5.0	3.0
Cyanide (p.p.m.)	2.0	2.0	2.0
Oils—mineral	Should be excluded by municipal ordinances.		
Oils—soluble	Removed to maximum practicable extent before discharge.		
Combustibles, etc.	Should be excluded by municipal ordinances.		
Free mineral acids	Should be neutralized at source.		
Acetylene generation sludge	Should be excluded by municipal ordinances.		

*Page 22, "Report—Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes," Allegheny County Sanitary Authority (January, 1948).

Whenever the proportion of wastes becomes so great that the sewage treatment plant becomes a wastes treatment plant, it is necessary for industry either to remove its wastes or to pretreat them to an acceptable degree. New sewage treatment plants may be designed to handle the industrial wastes of the municipality if their character and quantity can be predicted.

It is difficult but necessary that certain limitations be placed on the quantity of objectionable or toxic substances that may be present in sewage as received at the treatment plant. Such limits have been proposed by the Allegheny County Sanitary Authority. Table I has been taken from the Authority's recent report "Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes."

It is the writer's opinion that if these concentration limits are met there will be no difficulty in treatment by the usual sewage treatment processes. In fact, it is probable that these limits can be exceeded manifold for short periods without any harmful effect.

A committee is needed to establish maximum limits of objectionable constituents of industrial wastes that are proposed to be treated with municipal sewage.

*Reprinted from Sew. Wks. Jour., Vol. 21, p. 522 by permission.

UTILIZATION OF SEWAGE SLUDGE

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THE use of sewage sludge as a soil conditioner has its roots in antiquity. The Mongolian race has maintained high soil fertility for many centuries by the application of human feces and other organic materials to the soil. F. H. King's book, "The Farmers of Forty Centuries," provides illuminating reading in this respect.

The current literature is replete with references to the use of sludge. The Federation's Manual of Practice No. 2, "Utilization of Sewage Sludge as Fertilizer" alone reveals a bibliography of 251 current references on the subject. The reader is thus adequately provided with reference material.

This paper deals with certain salient facts concerning sludge utilization which either deserve repetition or on which the attempt is made to cast new light. Believing the old axiom that one picture is worth a thousand words the author recently presented pictorial evidence of the benefits of sludge in soil fertilization on his own premises.*

Sludges and Fertilizers

It is increasingly apparent that intelligent use of both sludge (or any humus material) *and* mineral fertilizer is necessary if either is to have maximum effectiveness for crop production.

Raw Primary Sludge

Raw primary sludge unless composted is unsatisfactory as a soil conditioner because of its effects on the soil and growing plants, and because of the health hazards involved.

Activated Sludge (Heat Dried)

Raw activated sludge after heat-drying is established as a superior sludge product. Such sludge retains most of its organic solids and it contains more nitrogen than other sludges.

In general, good crop growth is reported with raw activated sludge. The author would point out, however, that such sludge, if not well worked into the soil, encourages surface molds; odors may persist for some time from the decomposition of its organic matter. Some crop retardation may also be experienced immediately following its application unless the sludge is first composted with soil or harrowed into the soil for a time prior to planting the crops. Heat-dried activated sludge is safe hygenically. Not only pathogenic bacteria but also the cysts and ova of intestinal parasites and hookworm eggs are destroyed.

Digested Sludge

Digested sludges from all sewage treatment processes are materials of moderate but definite value as a source of slowly available nitrogen and some phosphate. They are comparable with farmyard manure except for a deficiency of potash. Their principal value is the humus content resulting in increased moisture-holding capacity of the soil and a change in soil structure which results in a greater friability. Like all humus materials, sludge stimulates the growth and propagation of angle worms which aid in soil aeration.

There is some loss of nitrogen when digested sludge is stored but this is not too significant. Seeds in sludge are effectively killed by digestion under heat except a few cucurbit and tomato seeds; these seeds are rarely a troublesome problem.

Reports of sickness traceable to use of digested sludges, either vacuum-filtered or air-dried, continue to be negative. Cram and Gilcreas have pointed out the potential hazard of transmission of parasitic infections with air-dried digested sludges as a result of handling the sludge or from sludge-contaminated vegetables eaten raw. Spreading of digested sludge in the fall and allowing it to freeze in cold climates in the winter is believed helpful in killing these organisms. Experience with actual parasitic infections is negative to date.

The author believes that if digested sludge used in cold climates is spread in the fall on land used for vegetables, then is ploughed or harrowed under in the spring (and no more is applied to the growing crops), health hazards from pathogenic bacteria or parasitic organisms may be avoided. To stipulate that certain vegetables which are eaten raw or grown in contact with the soil must not be grown in contact with air-dried digested sludge is a restriction which would make the use of this sludge of little value for the gardener who operates a small garden.

Grease

Grease of animal origin in digested or activated sludge may be considered harmless to soils. Excessive amounts of mineral oil, however, may well be detrimental. Raw primary sludge, not composted, may also cause soil clogging from grease.

* See "This is the Lot that Sludge Nourished," *Water & Sewage Works, June 1952.*

Memorandum on Use of Sewage Sludge as a Soil Conditioner

Dried digested sludge has been utilized in the past from sewage treatment plants in Connecticut as a source of humus or fertilizer for soils. Recently both technical and popular articles have appeared, pointing out the advantages of organic farming, so that a quickening interest in sludge utilization may be experienced.

The State Department of Health is concerned under the state law with the operation of public sewage treatment plants. There are outlined below the conditions under which sludge use on soils is permitted. In case of questions about sludge use, it is recommended that the local health officer be consulted and the health officers should always be advised in case of proposed transportation between towns. Superintendents and operators of sewage treatment plants are requested to see that all sludge users are informed of the following precautionary measures:

1. The spreading of raw (undigested) sludge in any form, unless heat-dried to a temperature of at least 1000°F. for ten seconds, should not be carried out. Septic tank sludge should be considered as raw sludge.
2. The discharge of liquid digested sludge on any land, other than the immediate grounds of a sewage treatment plant, is prohibited, unless the method employed and the discharge location are previously approved by the State Department of Health and the local health officer.
3. Air-dried, or vacuum filter dried, digested sludge, preferably stored for a period of several months, may be used on lawns, and the soil surrounding trees, shrubs, and flowers. It may also be used on land utilized for vegetable growing, provided the edible portion of the crops grow above the ground or the crops are such that they are cooked before eating.
4. In the case of vegetables grown in contact with the soil and eaten raw, dried digested sludge should always be applied to the soil the previous fall and plowed under either immediately or the following spring before the crop is planted. No additional applications of sludge should be made during the growing season.
5. Heat-dried sludge is safe for use under all conditions because of the destructive action of heat upon the bacteria.
6. The general public should be warned to avoid handling sludge with the bare hands and to wash the hands carefully with soap and hot water after sludge handling operations.

Sludge grinder at Meriden, Conn. Ground sludge is ready for spreading.

Sludge storage at Greenwich, Conn. Concrete platform at Grass Island Plant.

pH of Sludge Cakes vs. Liming Requirements

The pH of heat-dried activated sludge is low, generally averaging 5.0 to 6.0. Air-dried digested sludge after a short period of storage will normally drop to about pH 6.0. Digested sludge cake conditioned with lime for vacuum filtration has initial pH values ranging from about 10.2 to 11.2, but this drops rapidly when it is mixed with soil or more slowly on storage, as a result of loss of ammonia. Tests show the pH of lime-conditioned sludges drops to about 7.5 in two or three days so that danger of too alkaline a soil should not occur from the use of such sludge.

Experience shows that the continued use of any type of sludge unless previously conditioned with lime requires the periodic addition of lime to the soil to prevent harmful acidity. The author's own experience using an elutriated digested sludge conditioned with ferric chloride is that liming is required about every three years to maintain a soil pH between 6.5 and 7.0.

Horticultural references give optimum pH ranges for vegetables, shrubs and trees. Liming requirements in conjunction with sludge applications must be based on these values. In general, most vegetables and shrubs do well in soil having a pH range from 6.0 to 7.0; pH values of 5.3 to 6.0 are satisfactory, however, for potatoes, pumpkins, melons, strawberries, raspberries, watermelons, peppers, eggplant and tomatoes. A higher pH range of 6.4 to 7.6 is desirable for asparagus, cauliflower, cabbage, cucumbers, peas, onions, beets, spinach and lettuce.

The purpose of liming soils is not so much to create a certain pH value for a particular crop as to set up a balance for proper utilization of the soil nutrients. Following are some of the reasons for liming:

1. Lime neutralizes excessive acidity.
2. It favors decomposition of the organic matter by bacteria.
3. It will improve the physical condition of heavy soils.
4. It supplies calcium, one of the elements needed by plants.
5. It makes phosphorus in the soil more available.
6. It increases the effectiveness of organic materials (sludge) and commercial fertilizers.
7. Lime will precipitate certain elements such as copper, aluminum, manganese or zinc, which are sometimes present in excessive amounts, thereby reducing their solubility in the soil and preventing harmful effects. This action of lime is discussed further under the next heading.

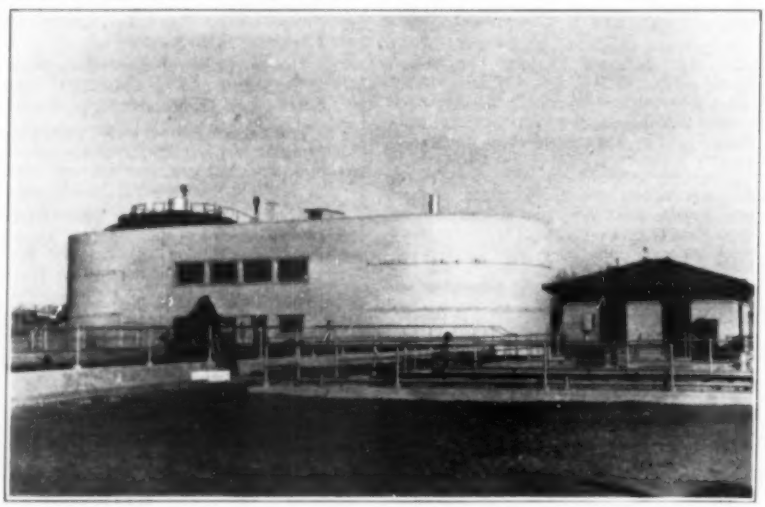
Soil long under cultivation, without adequate fertilization, such as commonly encountered in New England, is particularly benefited by lime applications. The lime should preferably be applied in the fall before using other fertilizers. Applications are usually at the rate of ½ to 1 ton of hydrated lime (or equivalent) per acre. This amounts to about 2½ to 5 pounds per 100 sq. ft. In small plots of land, either hydrated or ground limestone may be used.

Certain Elements in Sludge and Their Effect

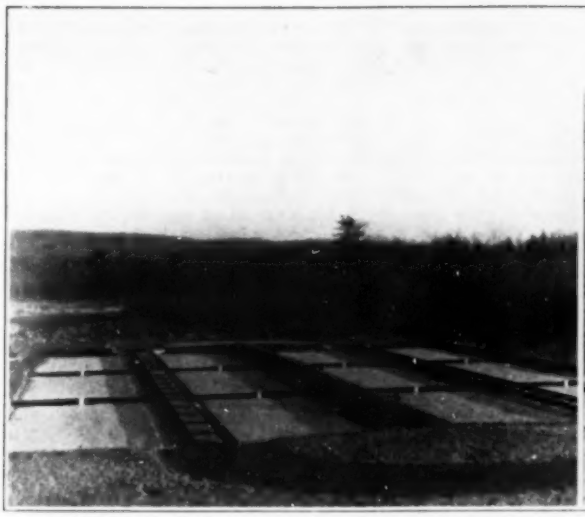
Spectrographic analyses of a number of digested sludges in Connecticut by the Connecticut Agricultural Experiment Station show relatively high concentrations of certain minor elements to exist as compared with other fertilizing materials. Thus the total zinc was found to range from 1700 to 3100 ppm, copper from 400 to 700 ppm, and boron from 130 to 360 ppm, even when no appreciable volume of industrial wastes is present in the sewage. The presence of so much zinc is attributed to galvanized metal piping, brass piping, human feces and rubber articles, the latter containing zinc oxide used as a filler. Excessive zinc in the soil appears to have much to do with reducing the yield of certain vegetables. Likewise copper, while beneficial in moderate amounts*, can be harmful to crops when present in excessive quantities. Boron, while essential in small amounts, may also prove toxic when applied at rates greater than 50 pounds as borax per acre.

A correction for the detrimental effects

* The Conn. Agr. Expt. Station recently reported increased yield and value of tobacco crops to which 20 lbs. of copper as copper sulphate was added per acre.



Modern digesters—for raw primary sludge—at West Haven, Conn.



Sludge drying beds at Plainville, Conn. Dry cake can be handled readily.

Sludge lagoon at Putnam, Conn. Dry sludge can be dug out for use.

of certain elements appears to be possible through lime applications. Lime will precipitate much of the soluble or available portion of these elements and reduce the amount available at any one time in the soil and hence that which will be taken up by the plants. Many users of sludge (where sludge has been applied to soil used for the growing of vegetables) have perhaps unwittingly avoided the harmful effects of these elements by periodic lime additions.

The author has noted no detrimental effects from these elements in sludge when sludge is applied to grass, trees or shrubs. So far as the author knows, the effects appear to be limited to certain vegetable crops.

The usual iron content of sludges is not harmful to soils. Sludges conditioned with ferric chloride may be used with safety.

Nitrogen-Fixation by Bacteria in Sludge

A. H. Niles reports that the nitrogen-fixing bacteria in sludge transform nitrogen in the air to useful compounds available to food plants. These bacteria also attack and break down the humus present in the sludge and soil.

Sludge Application Rate Affects Crop Yields

There are indications that first crop yields are improved by low application rates of sludge to soils. Dr. Herbert A. Lunt, Soil Scientist at the Conn. Agr. Expt. Station, finds rates of 10 tons per acre better than 20 tons per acre. The writer confirms this observation based on his own experience. The reduced yields with heavier applications of sludge are believed to be the result of toxicity from too high concentration of the elements mentioned previously.

Yields of subsequent vegetable plantings on soil previously treated with sludge are not so retarded nor are late-season crops likely to be appreciably affected. Increased crop yields have been reported by many investigators after the first year, these increases often extending into the third year.

Yields are improved by sludge fortification with mineral fertilizers. It is often more practical to apply the sludge and then add mineral fertilizers.

Various formulae for nitrogen additions as well as phosphate and potash additions may be found in many references.*

Stamford, Conn., sells heat dried sludge to commercial fertilizer producer. Top photo shows bagging equipment and lower photo shows loaded bags ready for shipment.

Seed Germination

Connecticut tests by Lunt show delayed or reduced germination of beans, spinach, beet and lettuce seeds (the only ones tested) on soils recently treated with sludge. Practically speaking, this is not serious since seed applications are usually ample to insure a good stand.

Barging Sludge to Sea

While at first thought this practice might appear to be the waste of a natural resource, from the ecological viewpoint, it at least affords in a limited area utilization of the sludge as a food for fish and for the fertilizing of sea plants.

Trends in Sludge Use

W. S. Foster in American City magazine for December 1950 finds a growing trend in use of liquid sludge for orchards and vineyards. Care should be exercised in the use of liquid sludge, however, since even *digested* liquid sludge is likely to produce temporary odors of nuisance proportion as well as unsightly conditions upon application to lawns or gardens.

Foster also reports, as the result of a survey, upon sludge sale by the larger sewage treatment plants to brokers for blending of sludge in commercial fertilizers. In California liquid sludge is being fortified before use on orchards. There is a desirable trend in Connecticut of utilizing waste heat from refuse incinerators for the drying of digested sludge. The refuse incinerators are built adjacent to the sewage treatment plants and permit sludge drying to a point that economical use can be made of the sludge product for distant hauls exceeding the usual practical haul of 5 to 10 miles for moist sludge cake.

*See for example: (1) Federation Manual of Practice No. 2, page 65. (2) "Increasing the Salability of Sludge" by P. N. Daniels, Water Works & Sewerage, August 1944. (3) "Sludge as Fertilizer in the War Emergency" by the author, Water Works & Sewerage, May 1943.

Grinding Digested Sludge

By shredding sludge to about pea size its salability is greatly enhanced. The author estimates that some 25,000 tons of digested sludge cake are currently available at Connecticut sewage treatment plants. Perhaps half of this production is finding its way back to the soil. Grinding would further increase its utilization in Connecticut and other states as indicated by the increased demand noted at the few plants where grinding is practised.

The Future of Sludge Utilization

In view of the dearth of farmyard manure and the need of many soils in the United States for humus, the outlook for sludge utilization should indeed be encouraging. Sewage works supervisors would do well to interest their local agricultural experts at State Agricultural Experiment Stations and follow their recommendations. The author believes that many soil experts are not alive to this potential source of humus and have insufficient information concerning its nature and possible uses. A recommendation from such experts will go a long way in promoting the development of a sound program. The recommendations of State and local health departments should also be followed.

In the author's state significant information on sludge use was recently forwarded to sewage works supervisors in the form of a "Memorandum on Use of Sewage Sludge as a Soil Conditioner." (See box.)

It should be emphasized that sludge is not a balanced food for plants. Its application, however, has a mechanical effect on the soil, and improves its texture. The continued exclusive use of commercial fertilizer represents unsound and dangerous agricultural practice. Soils repeatedly planted to growing crops require the organic humus supplied by manures, peat moss, green cover crops or sludges. The value of sludge should not be judged by comparison of chemical analyses with artificial fertilizers, but *by the results it produces in plant growth.* Sir Albert Howard has stated in this respect:

"We seem to be always thinking in terms of soil nutrients. This is a great mistake. In agriculture it is a question of the utilization of fungous tissue mobilized in the form of humus which really matters and which is one of the secrets of the agriculture of the East. This fungous question is far more important than nutrients and in this matter we have gone on completely wrong lines."

It has been stated that we are what we eat. Crops grown on impoverished soils will be impoverished themselves and our health may suffer in turn.

A recent recommendation of the New Zealand Ministry of Works' Committee on "Utilization of Organic Wastes," states:

"The design of all future sewage treatment plants in this country should take full cognizance of the potential value of sludge as a fertilizer."

Whenever practicable, our own cities would do well to take like steps to utilize this valuable natural source of humus and other soil building elements.

RATIO OF SLUDGE DENSITY TO VOLUME

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THE variation in sludge volumes with solids content changes determines the most effective use of sludge handling and other treatment facilities in a sewage treatment works.

In this all important consideration it is, of course, the amount of liquid mixed with the sludge solids that determines the volume to be handled, and since the volume varies so markedly with the per cent of solid matter contained, this fact has important significance to the sewage works operator and engineer. The effect extends to the operation of digestion tanks, concentration tanks, aeration units, pumping and piping facilities, sludge storage, and other treatment units.

It becomes apparent that all the efforts of a sewage works operator to secure a more concentrated sludge contribute sizeable dividends to plant efficiency and operating expense, when one considers that a rise in moisture content by a mere 2.5% means 100% more liquid volume to be handled per one hundred pounds of sludge solids, when the water content rises from 95% to 97.5%. By the same token a sludge of 99.5% water, as against 97%, has a volume 500% greater. When using, as a base, the same quantity of solids to be handled, a digesting sludge of 95% moisture occupies just one half the space of a sludge of 97.5% moisture. The significance of this matter is that the digestion period of the sludge may be doubled by what may look to be an insignificant decrease of only 2.5% water content. If a sludge with 95% moisture passes through a digester in a theoretical (calculated) time of thirty days, and the sludge becomes thinned to 97.5% moisture, two things happen to give a serious change in digester operation. These are:

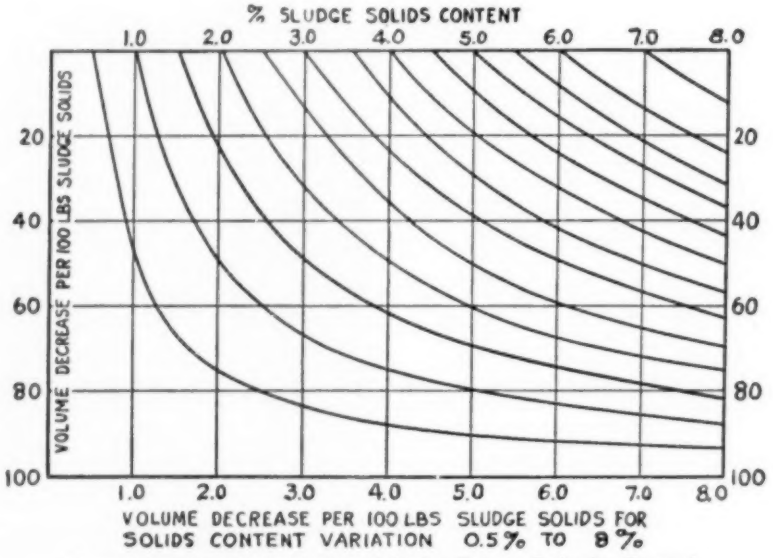
(1) The solids pass through the digester in one-half of the theoretical time (actually more nearly one-quarter of the time, due to disturbance of solids, dilution, and intermixing of new and old solids).

(2) It will require approximately 100% more heat input to maintain a given temperature in the digestion tank because there is twice the volume of liquid to be raised to the desired temperature.

The marked changes due to a combination of these two effects are not hinted in the mere 2.5% more moisture content of the sludge which appears in the operating records. On the other hand if we recorded sludge concentration in terms of pounds of solids per 1000 gals., or the reverse, rather than percent solids, the volume relationship would become very much more evident to us in following operating records.

The relation of moisture content to the volume of sludge handled magnifies itself many times in activated sludge practice. For example, the difference between a sludge of 99.5% and 97% water is represented by a volume reduction of the magnitude of 6 volumes reduced to 1 and is of very real consequence and importance. The meaning of sludge volume decrease to an operator of an activated sludge plant may be easily evaluated upon a careful examination of operating data and any permissible measure of securing sludge concentration has high justification in improved operation and economy.

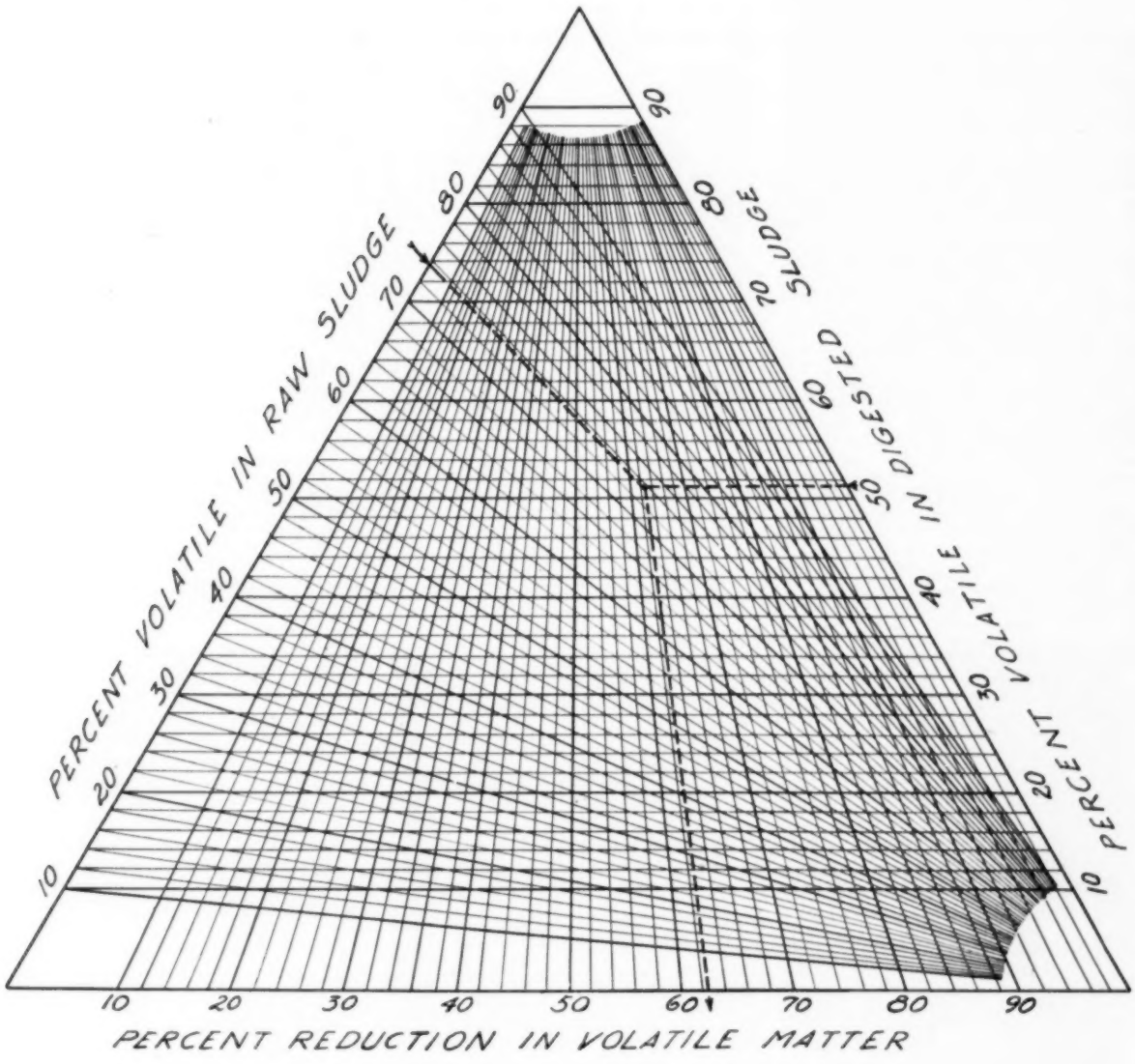
The accompanying graph shows the relation of sludge volume to solids content variations more fully than any number of words or further examples.



Curves Revealing Marked Effect of Sludge Volume Reduction Through Concentration.
Note that increasing solids content from 0.5% to 3.5% reduces volume to 1/6 original. This in the Activated Sludge Process is of great significance.

CHART FOR DETERMINING PER CENT SLUDGE DIGESTION

By FRED H. BURLEY
Supervisor Sewage Treatment Plant, Detroit, Mich.



IT IS generally conceded that an excellent index to effective sludge digestion and efficiency of digester performance is the degree of conversion noted of the volatile matter in the sludge passing through the digesters. The degree of conversion is best expressed as per cent reduction of volatiles entering in the form of raw solids.

Volatile matter converted during anaerobic digestion is either evolved as gases or remains in the mother liquor (supernatant) as soluble organic or mineralized substances. The amount of gas produced is variously estimated at from 16 to 20 cu. ft. per pound of volatile matter converted.

The writer has found frequent computations of per cent reduction of volatiles on this basis to be a valuable check on digester efficiency, particularly so when considering the average figures for volatiles in the raw and digested products on the dry basis, from which the true reduction can be computed according to the following example. Assume:

	Volatiles	Fixed
Raw Sludge	73.5%	26.5%
Digested	51.2%	48.8%

Since in the raw sludge there was 73.5 lbs. of volatile matter for every 26.5 lbs. of fixed solids, there was originally present in the raw sludge $\frac{48.8}{26.5} \times 73.5 = 135.4$ lbs. of volatile matter for every 48.8 lbs. of fixed solids. Therefore, the actual reduction is 135.4—51.2=84.2 lbs. of volatile for every 135.4 lbs. entering as raw sludge. The reduction on a per cent basis is, therefore,

$$\frac{84.2}{135.4} \times 100 = 62.2 \text{ per cent.}$$

As a time-saver the accompanying chart was developed. It is simple to use. The arrows and dashed lines indicate the manner in which the per cent volatile in the raw and digested sludge (taking the above example) is located on two sides of the chart and the lines followed toward the opposite apex and parallel to the base, respectively, to their intersection. The line projected from this intersection to the base reveals the percentage reduction in volatile matter.

EQUIPMENT AND TOOLS FOR SEWAGE WORKS*

SETH G. HESS
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Interstate Sanitation Commission, New York, N. Y.

A WELL designed and well equipped sewage treatment plant should have a complete complement of tools and equipment necessary to its proper operation. Quite often it is impossible to foresee, in the design of a plant, just what tools and equipment will be needed, and yet some attempt should be made to provide as much of the equipment as possible. Likewise, in the operation of a treatment works conditions and situations change, thereby making it necessary to increase the inventory of equipment and tools. In either case a list of tools, equipment, and materials for the operation of a sewage disposal plant will be helpful as a guide either to the designing engineer or the operator. Such a list has been prepared and is presented herewith.

Irrespective of the items appearing on any general list, it is essential that the manufacturer or supplier of various machines and equipment furnish the special tools and spare parts for their equipment and machines.

Obviously, various types of plants require different types of equipment. The number of operators available, their previous trades and experience likewise modify these lists. Some operators are adept in carpentry while others have a flair for working in metals. In either case it would be well to expand on the tools and equipment suggested in the following to meet the particular ability of the operators.

At some plants only the smallest repairs are handled, while in others there are sufficient personnel to permit practically all of the maintenance repair work to be done at the plant. Accordingly the tools will have to be modified to meet these conditions. The proximity of repair services likewise influences the type of tools that must be available.

The following list is indicative of the type of tools and equipment used in some hundred sewage treatment plants within the district of the Interstate Sanitation Commission (N.Y., N.J., Conn.) which extends about fifty miles across and includes New York Harbor and adjacent waters.

Equipment

- Adding Machine
- Alemite or Zerk grease guns for plant equipment
- Barricades
- Blower—Air, portable—gasoline driven
- Brooms—Street, ordinary, industrial type
- Brushes—
  - Flue
  - Paint and Whitewash
  - Scrubbing and long-handled
  - Wire
- Blocks and Tackle for ½-in. and ¾-in. rope
- Boots—Hip and knee
- Cans—
  - 5 gal. for gasoline, safety type
  - 5 gal. for kerosene, safety type
  - Rubbish
- Caulking Gun—for glass house windows
- Chain Hoist—one ton capacity
- Concrete Mixer—Portable, gasoline powered
- Dippers
- Electric Drop Light — explosion proof, with extension cord—200 ft.
- Electric Generator — portable, gasoline driven
- Electric Torch Light—1½ or 3 volts
- First Aid Cabinet
- First Aid Emergency Chart (first aid directions)
- Fire Extinguishers
- Fire Pails
- Flags—Danger, for street use
- Flag Tripods
- Flashlights—Hand
- Flood Lights (to operate from portable generator)
- Funnels—Assorted sizes
- Gaskets—Sheet rubber and Vellumoid Gasket Paper
- Gasoline Engine for operating 3/16-in. sewer rods mounted on a two-wheel trailer
- Gloves—Rubber and canvas, work
- Goggles—Safety
- Hydrometers—Battery and Alcohol
- Hose—
  - 2 or 2½-in. for flushing out sewers (with 4x2 or 2½-in. reducer)
  - 300 ft. Garden type
  - Spare Hose for chlorinator
  - 20 ft. suction with strainer and 100 ft. discharge hose for use with power operated pump
  - Nozzles—Shut-off type
- Ladders—
  - Extension to 20 ft.
  - Step
- Lanterns—Red, also white globes
- Laboratory equipment as required
- Mop and Handle
- Padlocks
- Paint Sprayer
- Pails—12 qt. heavy galvanized
- Pencil Sharpener
- Picks
- Pumps—2-in.-4-in. portable, self-priming centrifugal, diaphragm or piston, gasoline engine driven
- Rope—½, ¾ and 1-in. and sash cord or clothesline
- Rubber Raincoats, hats and suits
- Safety Equipment—
  - Explosimeter
  - Gas Mask (chlorine)
  - Harness (safety belt) with 25 ft. ¾-in. rope spliced on
  - Oxygen breathing apparatus (Chemox)
  - Oxygen deficiency indicator
  - Respirator (for paint spraying, dust, etc.)
- Scum Skimmer
- Sludge Sampling Equipment
- Sludge Shredder
- Sprayer—hand, fly
- Squeegees—Floor and windows
- Torches—Bomb type
- Truck—Light, for carrying equipment
- Two-Wheel Hand Truck
- Typewriter
- Vacuum Cleaner
- Waste Cans
- Wheelbarrow—Rubber-tired
- Wringer Buckets

Garden Implements

- Brush Hooks
- Garden Trowel
- Hedge Clippers
- Hoe
- Hose—
  - Garden type, approximately 300 ft.
  - Nozzles—Shut-off type
- Insect Sprayer
- Lawn Roller
- Mower—
  - Lawn, hand or motor operated
  - Edging
- Pruning Shears
- Rakes—
  - Wood
  - Steel
- Scythe
- Sickle
- Spade
- Sprinklers—Nozzle type

Materials and Supplies

- Alcohol or Anti-freeze
- Assortment of bolts, nuts, washers, screws, cotterpins, rivets, lock washers, cap screws, stud bolts, etc., stored in jars or cans
- Bricks—Common
- Calcium Chloride (for icy pavements)
- Caulking Compound and sewer joint compound
- Caulking Compounds, Durolite or equal, for glass house windows
- Caulking Yarn
- Cement
- Cement—Asbestos
- Chain—Assorted sizes and lengths
- Chamois Skins
- Cleaning Compound, broiler
- Cleaning Powders—assorted
- Cups—Drinking
- Cutter Wheels—spare
- Disinfectants (CN and others)
- Emery Cloth—assorted grades
- Fittings—Brass or Iron—assorted sizes
- Flashlight Batteries
- Fuses—Assorted
- Glass
- Graphite
- Grease—For lubrication
- Hose, Nipples and Clamps for garden hose, extra
- Iron and Boiler Cement
- Kerosene
- Lead and Lead Wool
- Light Bulbs
- Measures—Oil, 1 qt. and 1 pt.
- Mops
- Nails—Assorted sizes
- Oakum
- Oil for lubrication
- Oil—Rust removing, penetrating
- Packing for pumps
- Paint Remover
- Painter's Drop Cloths
- Paints—Turpentine, linseed oil, thinners, etc.
- Pipe Joint Compound
- Pipe Stock—depending on system
- Plugs—Rubber Expansion
- Polish—Brass
- Putty
- Rags—Clean and sterilized
- Sand—Stone or gravel
- Sandpaper—Assorted Grades
- Soap
- Solder
- Soldering Paste
- Spare Handles for hammers, hatchets and axes
- Spare parts for all machines and apparatus
- Sponges
- Steel Wool
- Tape—Friction and Electrician's
- Thermometers—Assorted
- Toilet Paper
- Towels
- Valve Grinding Compound
- Waste—Wiping
- Wicks—For torches and lanterns
- Wire—Annealed, No. 10 and No. 16

Tools

- Axes—spare axe handles
- Awls
- Bars—crow
- Bars—wrecking
- Bit brace and assortment of bits for wood and metal
- Blacksmith's anvil, tools, forge and hand blower
- Bolt stock and dies
- Breast drill and assortment of drills
- Calipers—inside and outside
- Calipers—micrometer
- Caulking tools—water main type (assorted sizes and types)
- Chisels—assorted
- Chisels—bull point
- Chisels—cape
- Chisels—cold
- Chisels—diamond point
- Chisels—round nose
- Chisels—assorted—wood
- Chisels—assorted—for air hammer
- "C" Clamps—assorted
- Cotter Pin Puller
- Countersink—assorted for wood or metal
- Cutters—wire
- Cutters—½-in. bolt
- Dies—assorted for bolt and pipe threading stocks
- Drills—assortment
- Drills—electric portable ¾-in. for twist drills No. 60 to ¾-in. with drill press stand mount
- Drills—electric portable ¼-in. for twist drills No. 0 to No. 60
- Drills—hand
- Drills—press, bench type

*In the preparation of this list the writer is indebted to Marshall B. Ferguson, Field Technician of the Interstate Sanitation Commission, and to Joseph Doman, Sanitary Engineer, Department of Public Works, Greenwich, Conn., and Leslie E. West, Chief Engineer of the Elizabeth Valley Joint Meeting, who have reviewed the list and very generously offered their comments. The list was also checked against an inventory of the equipment and tools at the sewage treatment plant of the Belgrave Sewer District of which Herbert O. Johnson is superintendent.

Drills—star drills of various sizes
Extractors—screw, various sizes
Files—assorted sizes
Files—flat
Files—half round
Files—round
Files—taper (triangular)
Files—wood rasp
Fire pot—including metal foot and wrought steel ladle—for use with B and S cast iron pipe
Flanging tools—for use with copper pipe
Flaring tools—for use with copper pipe
Fuse Puller
Gages—set of shim
Gages—test for pressure and vacuum
Glass Cutter
Grinder—electric or hand—bench type
Grinder—wheels, coarse, fine and wire brush
Hacksaw—adjustable frame with extra blades
Hammers—Ball pein—assorted sizes
Hammers—Blacksmith's type
Hammers—Caulking
Hammers—Claw
Hammers—Mason's
Hammers—Rubber Mallet
Hammers—Sledge type—various sizes
Hatchet
Jacks—screw or hydraulic—various sizes
Joint Runner—asbestos, for use with lead joints
Lathe—metal, 12-in. swing, 24-in. centers
Lathe tools and appurtenances
Lead Pot and Ladles
Levels—Line
Levels—Spirit—metal frame, 18-in.
Line—Mason
Manhole cover lifting hooks
Mattock
Nail Sets—various sizes
Oil Cans—several types and sizes as required
Packing Hooks
Packing Tools—assorted
Pipe Cutter
Pipe Cutter—wheels (spare)
Pipe Taps
Pipe Thread Taps (combination), ¼ to 2-in.
Pipe Threading stock with assorted dies
Pipe Tripod
Plane—Smooth, bench, 7-in.
Pliers—assorted sizes
Pliers—Diagonal cutting
Pliers—Gas
Pliers—Combination slip joint
Pliers—Needlenose
Pliers—Wrench
Plumb Bob
Puller—gear set
Punches—assorted sizes, center, drift
Putty Knives
Reamers—Hand, Taper, Pipe, Expansion
Rules—6-ft. folding.
Saws—Rip, crosscut, compass and keyhole
Saw Set
Saw Vise
Scale Platform
Screwdrivers—various sizes
Screw Pitch Gauge
Scribers
Sewer Rods and attachments, 3/16-in. and 5/16-in.—3-ft. lengths for house and main line connections
Sharpening Stone
Shears—Tinsmith's, straight and curved blades—assorted sizes
Shovels—Square Point, long and short handle
Shovels—Round Point, long and short handle
Snake—25-ft. spiral
Soldering Iron and appurtenances
Square—steel, large and small
Stamping Tools—steel, letters and numerals.
Straight Edge—Steel
Tampers
Tape—50-ft. steel
Tar Pot
Torch—Blow and gasoline
Trowels—floats, steel and cork assorted
Trowels—pointing
Valve Resetting Tool
Vises—bench and pipe, portable chain vise and stand
Voltage Tester
Wall Scrapers
Washer or gasket cutter for making own washers
Welding outfit with appurtenances, goggles and gloves
Wire Stripper
Wrenches—Adjustable—various sizes
Wrenches—Allen set screw
Wrenches—Box wrench set
Wrenches—Hydrant
Wrenches—Monkey
Wrenches—Open end—various sizes
Wrenches—Ratchet—socket set
Wrenches—Socket—set of various sizes
Wrenches—Spanner
Wrenches—Stillson—various sizes
Wrenches—Torque
Wrenches—Valve

SEWABAZOOKA FOR HOUSE CONNECTIONS

J. R. JACOBS
Superintendent
Public Works Dept., Moultrie, Ga.

STREET ditching operations frequently go below the level of existing sewers, crossing the house connections for at least one side of the street and necessitating some provision for continuation of service during the period the house sewers are broken or displaced. The problem of maintaining sewer service under these circumstances is readily solved by use of a shop-made gadget dubbed the "sewabazooka." More importantly, the apparatus keeps sewage out of the open ditch, thus avoiding contamination of the work in progress and eliminating odor complaints and unsightly conditions.

Essentially, the unit consists of two sheet metal tubes (Fig. 1) that telescope, as shown in Fig 2, to allow for adjustment to varying conditions. Lengths and sizes for a 4-in. house sewer installation are as shown in Figure 2. All materials are 24-gauge galvanized iron, the longitudinal joints being of the crimped downspout type. The joint between the reducer end and the outer sleeve is soldered.

To use the "sewabazooka," it is telescoped and the inner sleeve is slipped over the sewer coming from the house. By extending the unit as required, the reducing end is slipped into the pipe leading to the main sewer. For ordinary grades and flows leakage is prevented by the overlap of the slip joints. If, however, excessive flows or flat grades require tighter joints, packing with a little oakum or caulking compound generally will suffice.

The total cost of materials and labor for fabricating the unit illustrated, which is for a 4-in. house sewer, was $3.50.

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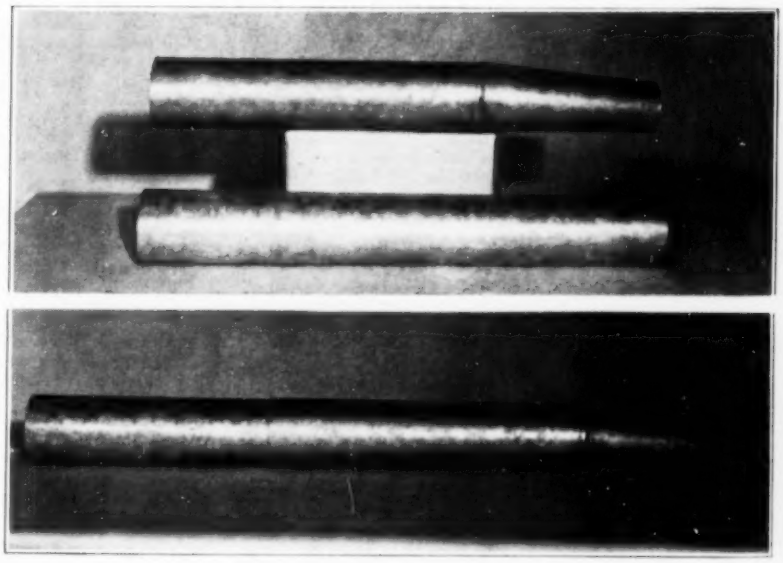


Fig. 1—Telescoping sheet metal sleeves are easily fabricated.

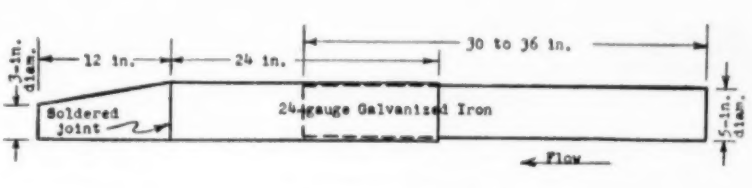


Fig. 2—Details of "sewabazooka" for 4-in. house connection

CONTENTS OF HORIZONTAL CYLINDERS

A Multiple Use Chart for Vertical as Well as Horizontal Tanks, Pipe Lines, Etc. →

By J. TARRANT

Assoc. M. Inst. C. E., A. M. I. Mech. E. Ruislip (Middlesex), England

THE alignment chart printed herewith gives a convenient method of finding the contents of cylindrical tanks placed with the axis horizontal for all depths of liquid in the tank.

It is usually the case that only a fair approximation of the tank contents is required, and the calculation by exact formula is not very readily done.

Formulas for horizontal cylindrical tanks contents are generally printed in two forms, one for use when the liquid level is above the centre and the other when the level is below the centre of the tank.

On the chart, the scale relating to the depth of liquid is continuous; that is to say, it applies whether the liquid level be in the upper or lower half of the section.

To use the chart, a straightedge is placed across the scales, and the intersections on the three scales give the related values. Line A gives the ratio of depth of liquid to the diameter of the tank; line B, the diameter of the tank in feet; and line C, the contents, in cubic feet and gallons, for each foot of length of the tank. In the example shown by the line across the chart, a tank 15 feet in diameter in which the contents are 10 feet 6 inches deep, will contain approximately 1,000 gallons per foot of length.

By using the fixed value of h/d = 1, the chart also gives contents per foot of height of a cylinder with vertical axis, and also the contents of full pipes per foot of length.

Sometimes the dimensions of a tank or pipe line will not be in feet, but the chart may still be used. The contents will be in units which correspond to the dimensional units, and the scale of gallons will not apply. For example, if the diameter is taken in inches, the contents, *read on the cubic feet scale*, will be in *cubic inches* per *inch* of length.

The calculation of contents is clearly based on the area of the segment of a circle, which is what the contents scale on line C shows, and the calculation of segmental areas, in any dimensional units, may be made by use of the chart so long as the cubic feet scale is read, and units ascribed to this which correspond to the units used for the diameter. When the diameter is in feet, the area of the segment is in square feet; for meters, the area is in square meters; for inches, in square inches, and so on.

WEIGHTS AND MEASURES

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound

Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)

27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
1 British bushel = 1.032 U. S. Bushel
8 quarts = 1 peck
4 pecks = 1 bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cp. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

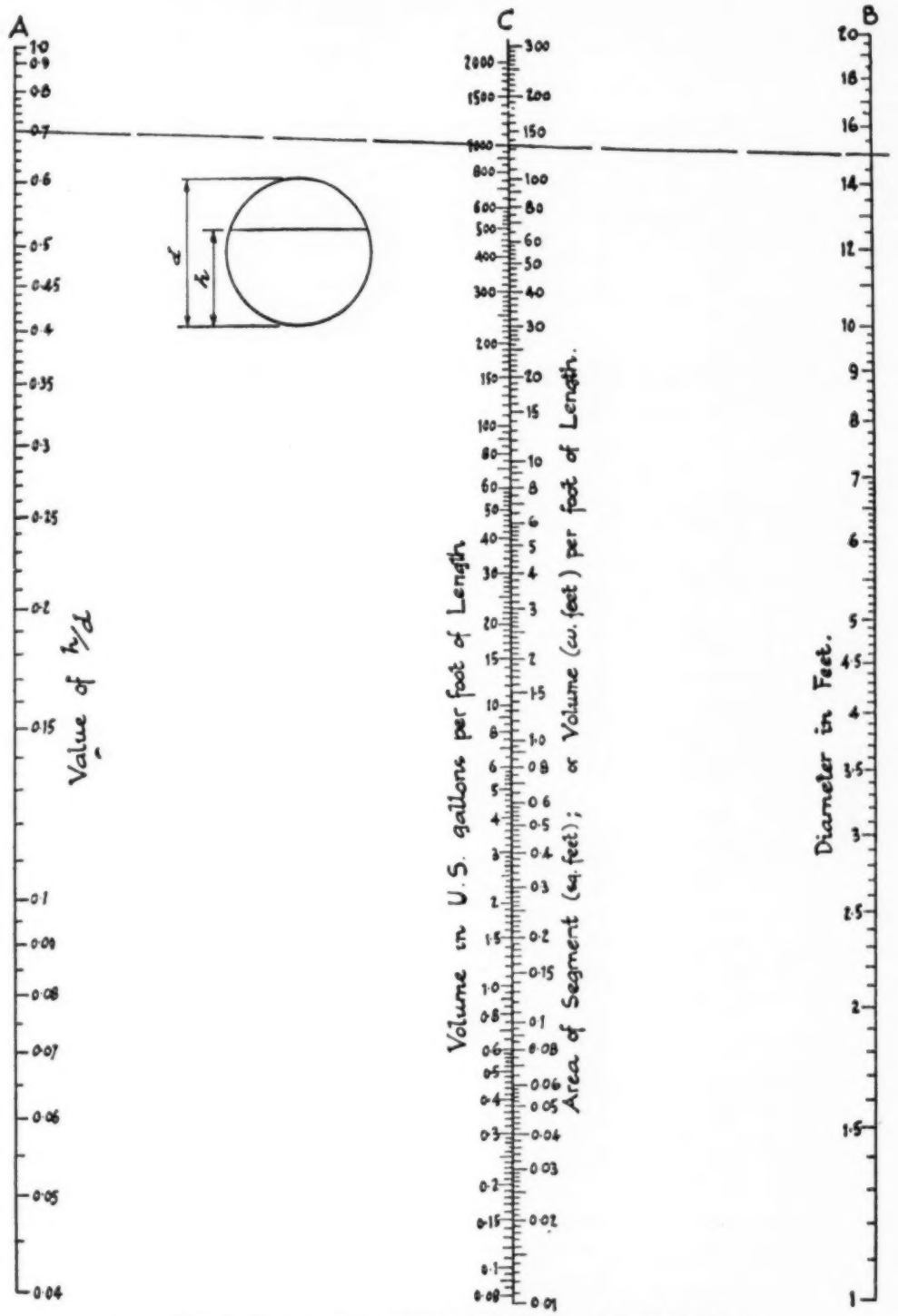
1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9,2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains



CONTENTS OF HORIZONTAL CYLINDERS.

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EQUIVALENTS AND CONVERSION FACTORS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4 1/2				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3 1/2			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2 1/2		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1 1/2		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1 1/4	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
3/4	88.18	15.59	5.66	2.05	1.00					
1/2	32.00	5.66	2.05	1.00						
3/8	15.59	2.76	1.00							
1/4	5.66	1.00								
1/8	1.00									

Diameter of Pipes	3	3 1/2	4	4 1/2	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4 1/2	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3 1/2	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.27	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.14	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

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